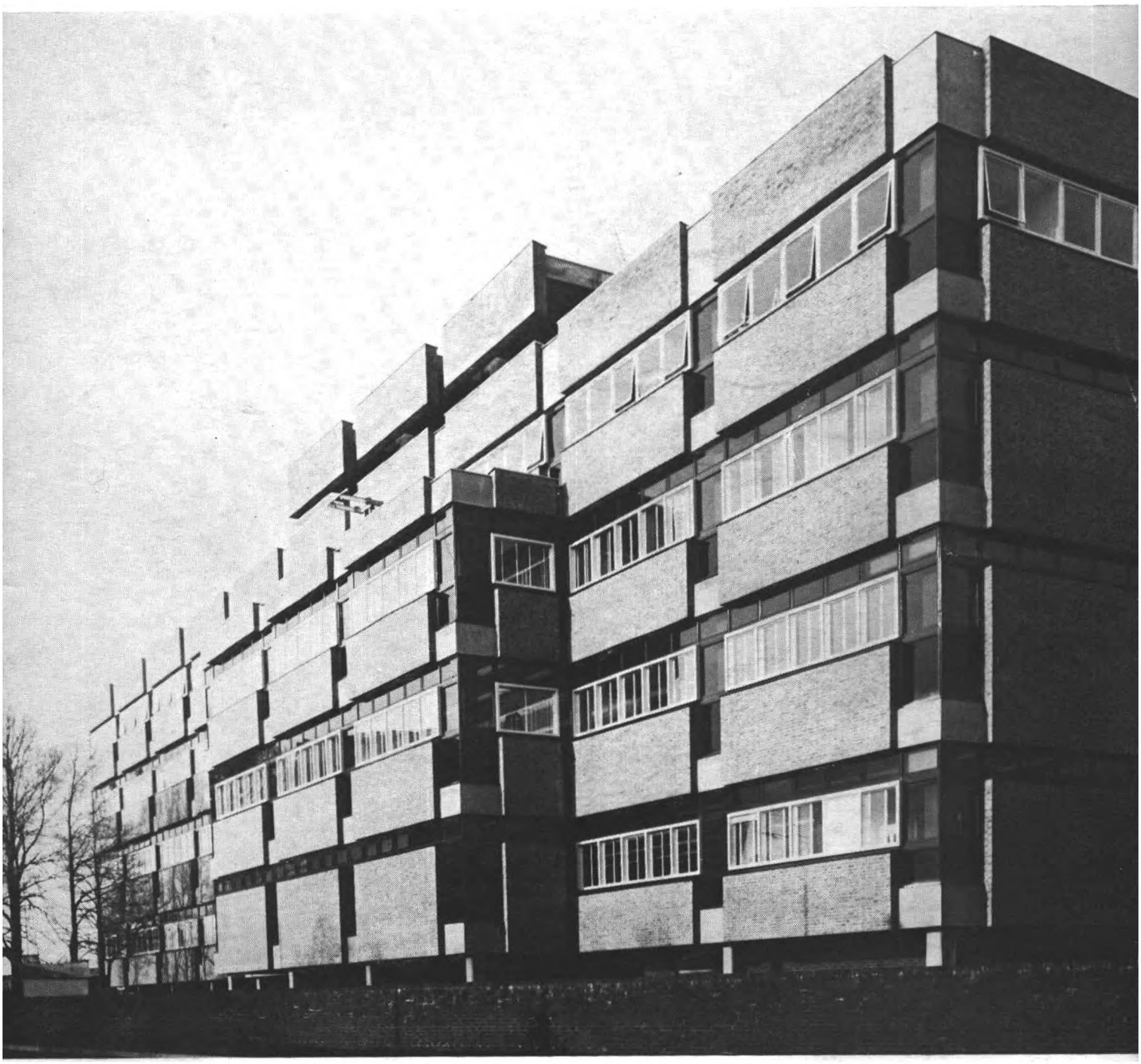
METEOROLOGICAL OFFICE

ANNUAL REPORT 1972



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ANNUAL REPORT
ON THE
METEOROLOGICAL OFFICE

1972

Presented by the Director-General
to the
Secretary of State for Defence

LONDON
HER MAJESTY'S STATIONERY OFFICE
1973

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FOREWORD BY THE DIRECTOR-GENERAL

This has been another very busy and challenging year for the Meteorological Office in which limitations on staff have made it increasingly difficult to meet all the demands for our services.

Occupation of the new operational building at Bracknell was completed in the spring when the Central Forecasting Office and the Telecommunication Centre joined the Computing Laboratory which had been installed there since the previous December. The building, which was formally opened by the Prime Minister on 6 October 1972, has been named the Richardson Wing in honour of Dr L. F. Richardson, F.R.S., the pioneer of numerical weather prediction (see Plates II–IV). The activities of this superbly equipped building are centred on the giant IBM 360/195 computer which has operated round the clock, seven days a week, throughout the year and, apart from difficulties imposed by power cuts, has given very little trouble. Dedicated almost entirely to our own work, it produces about 500 different computed weather charts each day and handles about 2500 research and other tasks each week.

The objective numerical forecasts are now based on a new 10-level mathematical model designed to predict the evolution of major weather systems over practically the whole of the northern hemisphere for up to at least 72 hours ahead. Such forecasts have been made twice a day since 1 August, each one involving about ten thousand million numerical operations on the computer. In addition, experimental forecasts are made twice daily with a refined version of the model to provide more-detailed predictions, especially of rainfall, on a 50-km grid covering most of Europe. This model is expected to become fully operational in 1973. A new scheme of integrating the equations has been undergoing trials and promises to cut the computer time required for such forecasts to only one-third.

The introduction of the new hemispherical model has made it possible to extend the ship-routeing service to cover the North Pacific Ocean as well as the North Atlantic Ocean and demand for this service has increased sharply in recent months.

The preliminary results of an important experiment to make continuous measurements of rainfall over the Chester Dee catchment by radar are most encouraging and suggest that, even in such a difficult hilly area, it should be possible to measure areal rainfall more accurately and conveniently by radar than with a conventional network of rain-gauges. This experiment, which is being conducted in collaboration with the Water Resources Board and Plessey Radar Ltd, may be extended to cover other sites. It is hoped that it will provide a basis for establishing a network of weather radars capable of locating storms and measuring rainfall over most of the country. In this connection a small team at the Royal Radar Establishment are studying a practical system for the processing, transmission and display of data from such a radar network and tests are planned to gain experience with a small network of three or four radars.

Demands for meteorological information and advice continued at a high level despite a mild winter. The number of non-aviation inquiries answered by the staff rose slightly to 1·58 million and the number of forecasts for aviation showed little change at 1·53 million.

The Research Directorate has taken advantage of the new computer to

develop and test complex models for investigating the evolution and predictability of weather and climate on a global scale. The governing equations have been integrated for periods of up to 100 days during which the model continually generates new and realistic weather systems without showing signs of becoming unstable. As a first step towards understanding the physical basis of climate and climatic changes, and of assessing the possibilities of these being induced by man-made activities, experiments have been conducted to examine the effects of large-scale anomalies in sea surface temperature and of melting of the Arctic ice. A new higher-resolution global model with about ten thousand grid points at each of 11 levels is being developed and should be working early next year. This should enable the Office to take advantage of the much improved coverage of observations to be expected from the First Global Experiment of the Global Atmospheric Research Programme scheduled for 1977 and to play a major part in the research associated with the Atlantic Tropical Experiment in 1974. The Office has recently established a new research group to tackle the numerical modelling of tropical weather systems and this will work closely with the International Scientific and Management Group of the Tropical Experiment which is now resident in Bracknell.

Research has continued on the mechanisms responsible for the production of raindrops and ice crystals, and instruments to measure the concentrations of nuclei, drops and crystals in natural clouds are being developed for installation in the C 130 aircraft shortly to be delivered to the Meteorological Research Flight. Instruments for the measurement of electric fields, electrical conductivity and droplet charges within clouds are being developed in collaboration with the University of Manchester Institute of Science and Technology and have undergone successful preliminary testing on the Varsity aircraft (see Plate IX).

A new investigation into the formation and dissipation of fog at Cardington has produced some very valuable data on the heat- and water-budgets of radiation fogs and on the role played by turbulent air motions.

The Meteorological Research Unit based at the Royal Radar Establishment has continued to use sophisticated radars to good effect to study the structure of rain-bearing systems, the production of clear-air turbulence and the structure of convection in the atmospheric boundary layer. Studies of the boundary layer itself are being turned increasingly to problems of practical interest such as fog and the dispersal of pollutants, and to problems of importance for the development of other aspects of meteorology such as the incorporation of boundary-layer effects in numerical weather prediction models.

A substantial investigation has been started, in collaboration with scientists at Cambridge and Oxford Universities and the National Physical Laboratory, to determine the natural composition of the stratosphere including rare chemical constituents and their variation. This is required in order to assess the changes that might arise from the operations of large fleets of supersonic transport aircraft. The programme covers research into the basic photochemical reactions which determine the atmospheric composition, the distribution of minor constituents within the stratosphere and numerical modelling of the structure and dynamics of the stratosphere. Close liaison is maintained with allied investigations in the United States and France.

The Office has become heavily involved in planning and technical studies for the European geostationary meteorological satellite being developed by the European Space Research Organization for launching in 1976, and in design studies of a remote atmospheric temperature sounder for the U.S. TIROS N series of satellites from 1975 onwards.

The Office has remained virtually at full strength throughout the year with wastage being made good by recruits of good quality, a substantial proportion being highly qualified graduates. After many years of high wastage it is gratifying to report that the turnover of Assistant Scientific Officers was markedly reduced, thereby decreasing the shortage of fully trained staff in this grade.

B. J. MASON

January 1973
Meteorological Office
Bracknell, Berks.

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FUNCTIONS OF THE METEOROLOGICAL OFFICE

The Meteorological Office is the State Meteorological Service. It forms part of the Air Force Department of the Ministry of Defence. The Director-General is responsible to the Secretary of State for Defence through the Parliamentary Under-Secretary of State for Defence for the Royal Air Force.

The general functions of the Meteorological Office are:

(a) Provision of meteorological services for the Army, Royal Air Force, Civil Aviation, the Merchant Navy and Fishing Fleets.

(b) Liaison with the Director of Meteorology and Oceanographic Services (Naval) and provision of basic meteorological information for use by the Royal Navy.

(c) Meteorological services to other government departments, public corporations, local authorities, the Press, industry and the general public.

(d) Organization of meteorological observations, including radiation and atmospheric electricity, in the United Kingdom and at certain stations overseas.

(e) Collection, distribution and publication of meteorological information from all parts of the world.

(f) Maintenance of certain British observatories.

(g) Research in meteorology and geophysics.

The Meteorological Office also takes a leading part in international co-operation in meteorology. The Director-General is the Permanent Representative of the United Kingdom with the World Meteorological Organization.

Except for the common services provided by other government departments as part of their normal functions (e.g. accommodation by the Property Services Agency of the Department of the Environment, and stationery by Her Majesty's Stationery Office) the cost of the Meteorological Office is borne by Defence Votes.

The gross expenditure on the Meteorological Office, including that on the common services, was approximately £13·2 million in 1972. Of the amount chargeable to Defence Votes, about £9·0 million represents expenditure associated with staff and £3·9 million expenditure on stores, communications and miscellaneous services. Some £2·9 million was recovered from other government departments and outside bodies in respect of special services rendered, sales of meteorological equipment, etc.

COMMITTEES

METEOROLOGICAL COMMITTEE

Terms of reference:

(a) To keep under review the progress and efficiency of the Meteorological Service and the broad lines of its current and future policy.

(b) To keep under review the general scale of effort and expenditure devoted to the meteorological services.

(c) To ensure the maintenance of adequate contacts between the Meteorological Service and those who use its services.

Membership at 31 December 1972:

Chairman: The Earl of Halsbury, F.R.S.

Members: Professor R. L. F. Boyd, C.B.E., F.R.S. (Chairman, Meteorological Research Committee) (*ex officio*)
Professor A. H. Bunting, C.M.G.
Sir Frederic Harmer, C.M.G.
Mr A. F. Hetherington, D.S.C.

Secretary: Mr D. Hanson (Secretary, Meteorological Office)

The Committee met three times in 1972.

ADVISORY COMMITTEE ON METEOROLOGY FOR SCOTLAND

Terms of reference:

(a) To review the development of meteorological science and its application to Scotland.

(b) To submit to the Meteorological Committee any proposal in connection therewith.

Membership at 31 December 1972:

Chairman: Dr B. J. Mason, C.B., F.R.S. (Director-General, Meteorological Office)

Members: Dr J. M. Caborn (University of Edinburgh)
Sir Samuel C. Curran, F.R.S. (Royal Society)
Professor G. M. Howe (University of Strathclyde)
Mr C. Mackay (Department of Agriculture and Fisheries for Scotland)
Professor H. Meidner (University of Stirling)
Mr J. Paton, F.R.S.E. (Royal Society of Edinburgh).
Professor P. A. Sheppard, C.B.E., F.R.S. (Royal Meteorological Society)
Mr J. W. Shiell (Scottish Development Department)
Dr J. H. Steele (Department of Agriculture and Fisheries for Scotland)
Professor D. W. N. Stibbs, F.R.S.E. (University of St Andrews)

Secretary: Mr D. R. Grant (Meteorological Office)

The Committee met once in 1972.

METEOROLOGICAL RESEARCH COMMITTEE

Terms of reference:

The Meteorological Research Committee will advise the Parliamentary Under-Secretary of State for Defence for the Royal Air Force on the general lines along which meteorological and geophysical research should be developed within the Meteorological Office and encouraged externally. It shall review progress and report annually.

It is empowered to appoint subcommittees, one of which shall be responsible for advising on the use of money allocated annually from Defence Votes for research projects conducted outside the Meteorological Office. The Committee will be responsible for co-ordinating the work of its subcommittees.

Membership at 31 December 1972:

Chairman: Professor R. L. F. Boyd, C.B.E., F.R.S.

Members:
Professor H. Charnock
Professor D. R. Davies
Instructor Captain R. R. Fotheringham, R.N. (Director of Meteorology and Oceanographic Services (Naval))
Dr E. R. R. Holmberg (Army Department)
Dr J. T. Houghton
Mr R. F. Jones (Deputy Director, Physical Research, Meteorological Office)
Mr E. Knighting (Deputy Director, Dynamical Research, Meteorological Office)
Dr B. J. Mason, C.B., F.R.S. (Director-General, Meteorological Office)
Mr P. J. Meade, O.B.E. (Director of Services, Meteorological Office)
Mr F. O'Hara (Procurement Executive, Ministry of Defence)
Professor R. P. Pearce, F.R.S.E.
Mr J. S. Sawyer, F.R.S. (Director of Research, Meteorological Office)
Mr A. E. Seddon (Natural Environment Research Council)
Professor P. A. Sheppard, C.B.E., F.R.S.
Professor R. C. Sutcliffe, C.B., O.B.E., F.R.S.
Wing Commander N. E. Wilkins, D.F.C. (Air Force Department)

Secretary: Mr F. E. Dinsdale (Meteorological Office)

The Committee met twice in 1972 and its subcommittees seven times.

PRINCIPAL OFFICERS OF THE METEOROLOGICAL OFFICE

DIRECTOR-GENERAL

B. J. Mason, C.B., D.Sc., F.R.S.

DEPUTY TO THE DIRECTOR-GENERAL

P. J. Meade, O.B.E., B.Sc., A.R.C.S.

DIRECTORATE OF RESEARCH

DIRECTOR — J. S. Sawyer, M.A., F.R.S.

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BOUNDARY LAYER RESEARCH	F. Pasquill, D.Sc.
GEOPHYSICAL FLUID DYNAMICS LABORATORY	R. Hide, Sc.D., F.R.S.
METEOROLOGICAL RESEARCH FLIGHT	D. G. James, Ph.D.
CLOUD PHYSICS Assistant Director	P. Goldsmith, M.A.
HIGH ATMOSPHERE Assistant Director	N. E. Rider, D.Sc.
Special Post	K. H. Stewart, Ph.D.

DYNAMICAL RESEARCH

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SPECIAL INVESTIGATIONS Assistant Director	J. Briggs, B.A.
FORECASTING RESEARCH Assistant Director	F. H. Bushby, B.Sc., A.R.C.S.
SYNOPTIC CLIMATOLOGY Assistant Director	R. A. S. Ratcliffe, M.A.
Special Post	J. M. Craddock, M.A.
PROFESSIONAL TRAINING AND PRINCIPAL METEOROLOGICAL OFFICE COLLEGE Assistant Director	D. H. Johnson, M.Sc., A.R.C.S.
DYNAMICAL CLIMATOLOGY Assistant Director	G. A. Corby, B.Sc.

DIRECTORATE OF SERVICES

DIRECTOR — P. J. Meade, O.B.E., B.Sc., A.R.C.S.

INTERNATIONAL AND PLANNING
Assistant Director — D. G. Harley, B.Sc.

FORECASTING SERVICES

DEPUTY DIRECTOR — V. R. Coles, M.Sc.

CENTRAL FORECASTING
Assistant Director — R. F. Zobel, O.B.E., B.Sc.
Chief Forecasting Adviser — T. H. Kirk, B.Sc.

DEFENCE SERVICES
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H.Q., Strike Command — E. Evans, M.Sc.

PUBLIC SERVICES
Assistant Director — L. Sugden, B.Sc.
London/Heathrow Airport — R. E. Farms, B.Sc.

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DEPUTY DIRECTOR — M. H. Freeman, O.B.E., M.Sc.

TELECOMMUNICATIONS
Assistant Director — E. J. Bell, C.Eng., M.I.E.E.

DATA PROCESSING
Assistant Director — N. Bradbury, B.Sc.

SYSTEMS DEVELOPMENT
Assistant Director — E. J. Sumner, B.A.

OBSERVATIONAL SERVICES

DEPUTY DIRECTOR — J. K. Bannon, I.S.O., B.A.

OBSERVATIONAL REQUIREMENTS AND PRACTICES
Assistant Director — J. H. Brazell, M.Sc.
Marine Superintendent — G. A. White, Captain, Extra Master

CLIMATOLOGICAL SERVICES
Assistant Director — P. F. Illsley, B.Sc.

AGRICULTURE AND HYDROMETEOROLOGY
Assistant Director — J. Harding, O.B.E., B.A., M.Sc.
Special Post — L. P. Smith, B.A.

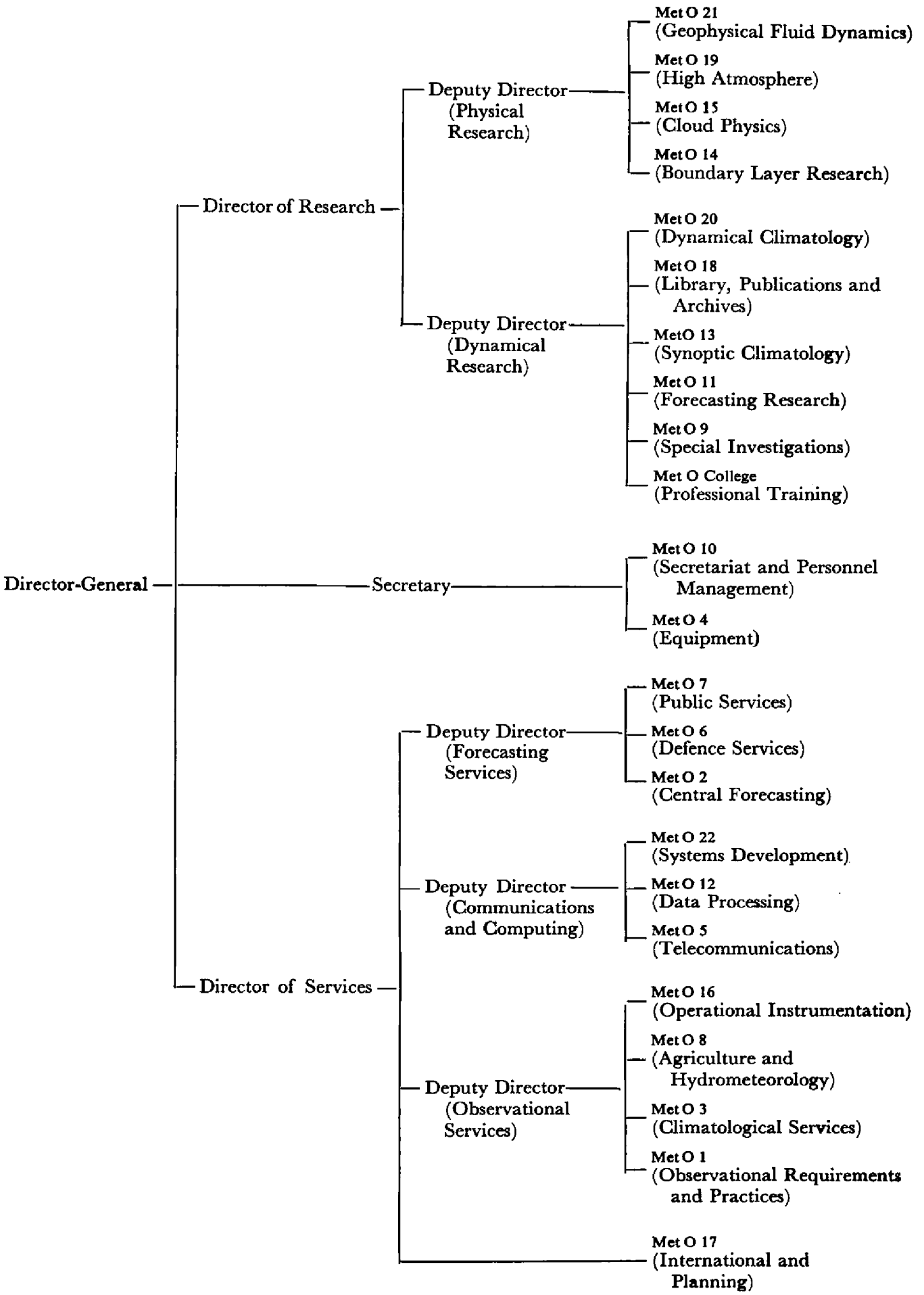
OPERATIONAL INSTRUMENTATION
Assistant Director — M. J. Blackwell, M.A.

SECRETARY, METEOROLOGICAL OFFICE — D. Hanson, M.A.

PERSONNEL MANAGEMENT — W. D. S. McCaffery, B.Sc.

METEOROLOGICAL OFFICE HEADQUARTERS ORGANIZATION

(at 31 December 1972)


Director-General
Director of Research
Deputy Director (Physical Research)
Met O 21 (Geophysical Fluid Dynamics)
Met O 19 (High Atmosphere)
Met O 15 (Cloud Physics)
Met O 14 (Boundary Layer Research)
Deputy Director (Dynamical Research)
Met O 20 (Dynamical Climatology)
Met O 18 (Library, Publications and Archives)
Met O 13 (Synoptic Climatology)
Met O 11 (Forecasting Research)
Met O 9 (Special Investigations)
Met O College (Professional Training)
Secretary
Met O 10 (Secretariat and Personnel Management)
Met O 4 (Equipment)
Director of Services
Deputy Director (Forecasting Services)
Met O 7 (Public Services)
Met O 6 (Defence Services)
Met O 2 (Central Forecasting)
Deputy Director (Communications and Computing)
Met O 22 (Systems Development)
Met O 12 (Data Processing)
Met O 5 (Telecommunications)
Deputy Director (Observational Services)
Met O 16 (Operational Instrumentation)
Met O 8 (Agriculture and Hydrometeorology)
Met O 3 (Climatological Services)
Met O 1 (Observational Requirements and Practices)
Met O 17 (International and Planning)

THE DIRECTORATE OF SERVICES

Special Topic—Data Processing Services

Introduction

The Meteorological Office has a long history of using machine methods for data processing. In 1920 punched-card machines were introduced for the processing of meteorological observations made at sea and it is believed that this was the first use of such machines by a national meteorological service. Over the subsequent decades the facilities of the punched-card installation (PCI) were extended and the punching of data on cards and their subsequent machining were introduced more widely in the Office. For several decades the PCI provided the prime means for automation of the rather laborious processing of large quantities of meteorological data, particularly for climatological purposes. In the early 1950s the Meteorological Office took another momentous step in the use of new data-processing facilities. This was the use of electronic computers which were then becoming available. At this time the emphasis and primary goal were different, viz. the use of the speed of computation available from electronic computers to attempt the solution of the mathematical equations of motion of the earth's atmosphere and, by integrating those equations forward in time, to attempt to make objective meteorological forecasts. The other special topic in this *Annual Report*—Research on numerical forecasting (pages 69–74)—describes some of the achievements to date. In this article it is sufficient to note that computational facilities were initially hired on suitable computers in the 1950s. The work soon showed sufficient promise to justify the acquisition by the Meteorological Office of its own computer—a Ferranti Mercury computer which was installed in the HQ Research Directorate in 1958. This machine was used almost solely for research. Good progress was made and in 1965 a more powerful computer—an English Electric Leo KDF9 computer—was installed in the Services Directorate. There were two main aims. Firstly to establish, on a routine basis, a system of objective mathematical analysis and prognosis leading to the production of twice-daily charts of pressure and temperature over as large an area as possible of the northern hemisphere. Secondly to make use of computer developments to simplify and facilitate the handling of the vast amounts of climatological data received. Both objectives have been achieved. In the winter of 1966 the KDF9 computer was being used operationally for the routine production of numerical analyses and prognoses using a 3-level model of the atmosphere. This soon proved to be successful and reliable and, until mid 1972, the KDF9 was the main operational computer. The second objective has also been achieved since much of the processing of the climatological and observational data received by the Office is currently performed on a computer. The work was proved largely on the KDF9 and much was done for several years on that machine. Research on more complex models of the atmosphere for numerical forecasting held promise of significant improvements beyond those of the 3-level model. However, the KDF9 was not sufficiently powerful to support such research and the Research Branches bought time on the more powerful International Computers Limited 'Atlas' computers at Manchester University and at the Science Research Council's establishment at Chilton near Harwell. As the work progressed the more complex models continued to show promise

and in 1966 a small group was established in the Office to commence work on the acquisition of a new, much more powerful, computer, to replace the KDF9 computer. At the end of 1969 an order was placed for the powerful 360/195 computer from International Business Machines Ltd (IBM) for delivery and installation at the Office's Bracknell Headquarters in the last quarter of 1971. A new building to house the 360/195 computer and its supporting technical equipment (together with the telecommunication system and the Central Forecasting Office) was constructed and occupied in phases. The new computer was installed on time, commissioned, accepted and handed over for Meteorological Office use by mid December 1971. During 1972 it has been operated continuously and brought into full operational use for numerical forecasting using a new 10-level model of the atmosphere.

IBM 360/195 *computer installation*

The 360/195 computer at Meteorological Office Headquarters, Bracknell comprises:

(a) *Central Processing Unit.* The Central Processing Unit (CPU) has a basic machine cycle time of 54 nanoseconds (10^9 nanoseconds = 1 second). The main core store consists of 1 048 576 bytes (each byte comprising 8 binary digits (bits)) and has a cycle time of 756 nanoseconds. The CPU also has 32 768 bytes of high-speed buffer storage (with a cycle time of 54 nanoseconds) which provides the principal means of reducing average access time to the core storage and thereby contributes very substantially to the speed of computation. The CPU communicates with the rest of the system via channels. There are three block multiplexer channels, each of which can pass data at a maximum rate of 1·5 megabytes per second. There are also two byte multiplexer channels with four selector sub-channels. These selector sub-channels can operate at a maximum transfer rate of 180 K (K = 1024) bytes per second. The two multiplexers can operate simultaneously and, together with four selector sub-channels, can yield a maximum transfer rate of 852 K bytes per second.

(b) *Fixed-head disc.* The fixed-head magnetic disc has a storage capacity of 11·2 megabytes and an average access time of 5 milliseconds. Data can be transferred at up to 1·5 megabytes per second. This unit provides the very fast transfer rate necessary for certain functions connected with numerical forecasting for both operations and research.

(c) *Exchangeable magnetic-disc drives.* There are 12 addressable and exchangeable magnetic-disc drives, arranged in banks of six units, each bank being attached to a separate disc-control unit (see Plate V). The 12 addressable drives provide 1200 megabytes of on-line storage. Data can be transferred at a maximum rate of 806 K bytes per second with an average rotational delay time of 8·3 milliseconds and an average seek time of 30 milliseconds.

(d) *Magnetic-tape units.* Of the nine magnetic-tape units, six are 9-track drives, one is a 7-track drive and two are KDF9 tape drives (see Plate VI, upper photograph). The 9-track drives handle half-inch magnetic tape with a packing density of 1600 or 800 rows per inch (1 inch = 25·4 mm). The 7-track drive handles half-inch tapes at 200, 556 or 800 rows per inch. It handles IBM-compatible tapes and can also be switched to read or write an industry-compatible tape with a BSS 3968 tape mark. The KDF9 tape drives are attached

to the system through special hardware so that KDF9 three-quarter-inch tapes may be read and written on the 360/195.

(e) *Card reader and card reader/punch.* Both card readers have a reading speed of 1000 cards per minute and the card punch operates at 300 cards per minute (see Plate VI, lower photograph).

(f) *Paper-tape readers and punches.* There are two paper-tape readers with a maximum speed of 1000 characters per second and two paper-tape punches with a speed of 120 characters per second (see Plate VI, upper photograph).

(g) *Line printers.* There are two fast wide line printers with 150 print positions per line and a print-out speed of 2000 lines per minute. There is one standard printer with 132 print positions per line and a speed of 1100 lines per minute. (See Plate VI, lower photograph).

(h) *Graphic displays.* Two graphic displays have been attached. One is located adjacent to the Computer Room (see Plate VI, upper photograph) and the other in the Central Forecasting Office (see Plate VIII, lower photograph). Each is equipped with a light-pen, alphanumeric keyboard and program function keyboard. The cathode-ray-tube screen provides a 30 cm × 30 cm display area and has a 1024 × 1024 matrix of addressable points.

(i) *Terminals.* Six teletype terminals are attached to the system. There are also two alphanumeric cathode-ray-tube type terminals. The terminals operate under the control of the Conversational Remote Job Entry program and they are used as remote-entry stations.

(j) *Plotter.* A Calcomp 1670 Computer Output on Microfilm (COM) device is installed in the Computer Room and can be operated either as an on-line device or as an off-line device using a 9-track magnetic tape. It is a very high-speed plotter which records data on to 16-mm or 35-mm film which is subsequently processed speedily in an adjacent room by an automatic film processor. Hard-copy enlargements (14·5 magnification) can be subsequently produced on a Rank Xerox 1824 Universal Printer which is installed in the Central Forecasting Office.

Figure 1 illustrates the logical interconnection of these several individual units of which the system is composed. The 360/195 is a very much larger and much more powerful computer than either of its predecessors at the Meteorological Office.

Services provided

(a) *For numerical forecasting for operational purposes.* Since July 1972 these services have been provided on the 360/195 computer. There are two operational runs starting at 03 and 15 GMT daily utilizing observed data for much of the northern hemisphere for 00 and 12 GMT, and forecasts for a period of up to 72 hours ahead are made on each run. Two additional runs are made at about 1245 and 0045 GMT to utilize the greater amount of synoptic data for 00 and 12 GMT which has been received since the 03 and 15 GMT operational runs. The prime purpose of these additional 'updating' runs is to provide the best possible analyses and forecast values for 12 hours ahead, which are then used in the subsequent operational run. These runs also permit some human intervention in the objective scheme and this also assists in maintaining continuity and coherence in the objective computer-based system.

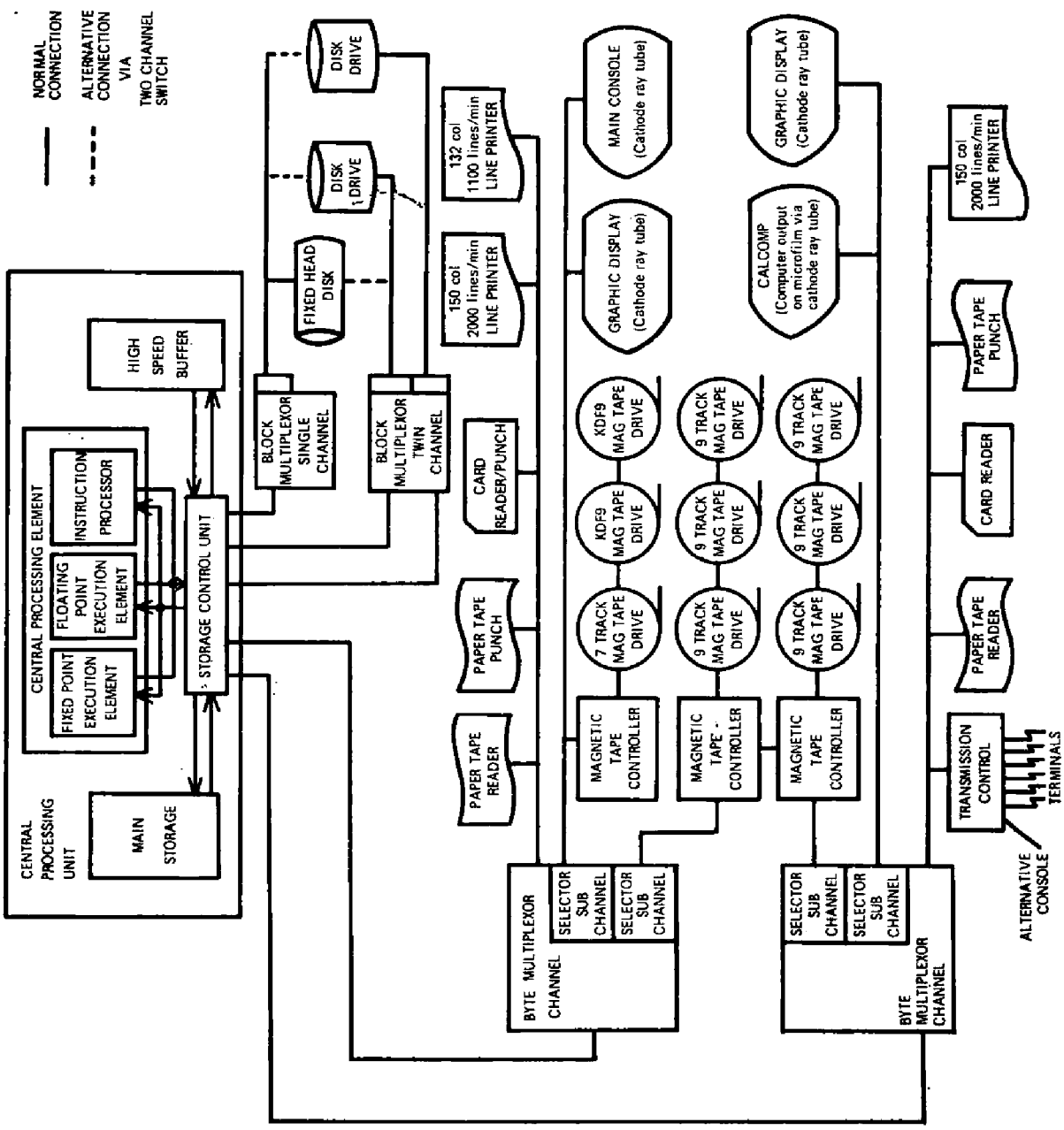


FIGURE 1—METEOROLOGICAL OFFICE IBM 360/195 COMPUTER SYSTEM

The majority of the results are printed out on a fast wide line printer which is loaded with continuous computer stationery especially pre-printed with suitable geographical backgrounds. Some output charts are also prepared using the Calcomp 1670 COM unit which produces microfilm which is subsequently fed into a Xerox 1824 Printer to produce charts of the size of about 55 cm × 45 cm. Some of these charts are distributed to the Central Forecasting Office where they are used directly by the forecaster. Other charts are sent to the Telecommunication Centre where they are mounted on facsimile transmitters and sent to many outstations where they are used by forecasters in providing meteorological services to military and civil aviation, industry, commerce and the general public.

Some of the output from the operational programs is taken in the form of punched paper tape. This information consists primarily of upper winds and temperatures over areas and at levels of interest to aviation and is required for flight-planning and air-traffic-control purposes. The paper tapes are passed to the Telecommunications Branch for transmission to BOAC, to Air Traffic Control Centres, and to meteorological offices at selected Royal Air Force units.

(b) *For the observational and climatological branches.* One of the objectives for the KDF9 computer was to utilize its power and facilities for handling the vast amount of observational and climatological data. Very good progress has been made and much of the basic processing of data is accomplished by using the KDF9 computer. The chain of events is rather long. Data are received from many of the observing stations in written form via postal services. The data are then hand punched either on cards or on paper tape and the punched data are read into the KDF9 computer. Processing then takes place by means of a wide range of computer programs which subject the data to tests for internal consistency, for sequential consistency and, in some cases, for areal consistency. The records of observed data and the computer output from the partly processed data are often returned to the relevant climatological branch for the checking of suspect values and, if such values are found to be in error, corrected values are then returned for subsequent punching. The corrected data are then also read into the computer and further programs merge the corrected data with the original data to produce the results in the required formats. Much of the information required by the climatological services for surface and upper-air observing stations, for rainfall stations and for marine observations from the voluntary observing fleet are processed in this way.

Very good progress has been made in preparing programs and procedures for transferring this work for the observational and climatological branches from the KDF9 to the 360/195 computer in the early part of 1973.

Some of the observational data (e.g. radiation data) are recorded directly on punched paper tape and the initial hand punching is avoided. Some other equipments which record data on magnetic tape are being brought progressively into use. Hand keying for these data is avoided but there is usually some transcription required before data can be read into a standard peripheral on one of the main computers.

(c) *Services for the Forecasting Research and Dynamical Climatology Branches.* These branches are carrying out research which involves the solution of complex mathematical equations based on the equations of motion of a compressible

fluid and on various atmospheric models which are postulated to simulate the earth's atmosphere. Access to a very powerful computer for substantial periods of time is an essential support service for these branches if they are to carry out significant research and make reasonable progress. Both branches submit large computational tasks for running on the 360/195 computer. Services for the Forecasting Research Branch currently include the running of a 10-level model of the atmosphere for a fine-mesh rectangular grid for much of the North Atlantic and Europe twice daily as routine, which leads to the production of detailed forecast charts for 36 hours ahead (see pages 70–74 of the Research Directorate special topic). The Dynamical Research Branch is currently working on a detailed model of the atmosphere for the whole globe and is currently proving the computer programs and examining some initial trial integrations. When the work is a little more advanced the Branch will need greatly increased computer times to produce long integrations of the model for many days or weeks ahead.

(d) *Services for the Systems Development Branch.* This Branch was set up in 1971 and is working on many new computer-based projects both on its own and also in collaboration with other branches in the Services Directorate. As the projects come to fruition and are implemented it is expected that there will be a significant increase in the data-processing services required by this branch or by other branches which it has assisted to develop more comprehensive routines.

(e) *Services for other branches.* In addition to the above services which are described in some detail, data-processing facilities are provided to many other branches. For example the pre-processing of data for the Synoptic Climatology Branch is carried out on the 360/195 computer on a regular, virtually daily, basis and is closely interwoven into this branch's procedures for long-range (monthly and seasonal) forecasting. The staff of the Special Investigations Branch also make demands on the computers for processing data to support their investigations and also for operational research into forecasting techniques. Data-processing services are also provided to branches dealing with boundary layer research, cloud physics and the high atmosphere. Some work is also done to support the Geophysical Fluid Dynamics Laboratory.

(f) *For publications.* The computer is used on a routine basis to prepare paper tapes for subsequent use with electric typewriters to produce automatically the master copy for printers of the tabular sections of the *Daily Weather Report* and the *Daily Aerological Record.*

Some experimental work has been carried out on the preparation of some of the climatological information in a suitable form on magnetic tape for subsequent use by the printers for automatic typesetting.

(g) *Services for the Data Processing Branch.* The Data Processing Branch is itself a user of the computer for its own purposes. Services are needed to develop and maintain the software routines (known as the Operating System) which are resident in the 360/195 and are used to instruct the computer to carry out the functions required by the Office. In addition there are several software packages which are run to monitor the use of the computer, to produce accounting information and also to provide statistics which are helpful in showing which parts of the computer system, the procedures or organization might usefully be changed so that the computer may provide the best possible service having

regard to the workload which itself is subject to change from time to time. In addition to these managerial and control functions the branch is also responsible for a complex suite of programs for reading-in the large quantities of paper tape containing synoptic data which are produced by perforators in the Telecommunications Branch, for recognizing the data and for subjecting the data to many computer programs for the quality control of the data—both for internal consistency and also for temporal and spatial consistency. Subsequently the data are sorted and stored in the computer to provide a synoptic data bank. The Branch has provided programs for access to and retrieval of data from this synoptic data bank for a variety of day-to-day operational purposes. For example selections from these routines form the starting stages of the operational computer runs on the 360/195 for numerical forecasting.

(h) *General services.* In addition to the facilities for the general development of programs which are provided by the computer room and its supporting ancillary services the Data Processing Branch answers a substantial number of queries from branches and also serves to concentrate experience and knowledge of hardware and software problems. The unit also advises on standards for documentation and it organizes training in programming for the 360/195 as required by branches. The Branch also provides a data-preparation service for the punching of programs and of some limited amount of data for test purposes.

The future

In recent years there have been significant developments in the design and production of equipment for the keying of data and their recording on magnetic tape, and the idea of converting from the punching of holes in paper to the keying and recording of data on a magnetic medium for subsequent direct mounting on a computer was attractive. During 1972 an operational requirement for such a new data-entry system has been issued and new equipment is about to be ordered. Delivery is expected early in 1973. Significant improvements in production are expected and some easement of the handling of punched cards and paper tape will be welcome. There will still be a need for some equipment for the machining of cards but this is expected to be at a lower level than previously and further reductions are expected as more and more data are recorded and handled on magnetic media.

Much new work is planned for the 360/195 computer. Planning and programming are well advanced for the introduction of automated plotting equipment into operational use in 1973. This workload is expected to build up and require the routine production of a wide variety of charts and diagrams to a very close operational timetable. Much more work is planned for the wider use of remote terminals, both of the simple alphanumeric type and also of the more powerful graphic type. Both sorts of terminals offer considerable potential benefits to several types of work in the Office. The Systems Development Branch are planning comprehensive machinable archives of meteorological data for the 360/195 together with associated access and retrieval routines to facilitate the use of the archives. There are further developments planned for some meteorological instruments in the field to record directly on magnetic tape. There are plans for the provision of an electronic interface between the main scientific computer and the computer-based automated telecommunication centre of the future. In addition forward estimates of future computing

requirements by branches have already revealed that some enhancement to the main computer will be required. The application of improved computer techniques in many branches of the Office offers much potential for the future, which is faced with both a determination to succeed and a deep confidence which has developed from the significant achievements in recent years.

Forecasting Services

Central Forecasting Office

Although the main aims and objectives of the Central Forecasting Office (CFO) have remained much the same as in recent years, there were considerable changes in the *modus operandi* in 1972. In particular CFO has been rehoused in the new Richardson Wing and a new forecasting model of the atmosphere has been brought into operation.

The new accommodation is commodious and is nicely furnished both aesthetically and functionally. The forecast room and suite of rooms leading off are air-conditioned, double-glazed and carpeted, so that a quiet, agreeable working environment has been created. There is an adequate lift and conveyor-belt installation to ensure the speedy interchange of both raw and processed data between CFO, the telecommunication centre and the computing laboratory, which are situated on the two floors below. Two views of the forecast room are shown in Plate VIII.

A great deal of work was carried out in collaboration with the Forecasting Research Branch during the first six months or so of the year, primarily to assess the performance of the 10-level primitive-equation atmospheric forecasting model in a series of trials. The trials were based on twice-daily runs of forecasts at various levels in the atmosphere for periods of up to 72 hours ahead on the IBM 360/195 computer. During the course of the trials some minor defects were exposed and rectified. The model was used to make predictions over two areas, a large octagonal area covering most of the northern hemisphere, and a smaller rectangular area covering most of western Europe and the North Atlantic as far as Newfoundland. Following the trials it was decided to adopt the octagonal model operationally from 1 August. All the necessary programming required to obtain the output needed on an operational basis was completed by that date and the model has been satisfactorily used regularly ever since. The rectangular model is still under trial.

The 3-level vorticity model continued in use on the ICL KDF9 computer until 30 April. The new IBM 360/195 computer was brought into use operationally on 1 May, using the 3-level model by means of a specially acquired program which simulated the KDF9 instructions on the IBM computer. No use is now being made of the 3-level model, but it is held in reserve in case of major breakdown when it could be used on any available KDF9 computer.

A further major change in procedure was introduced on 1 November when the upper-air forecasting section was enlarged by the addition of a subsection which produces the flight documentation, with the exception of significant-weather charts, needed at London/Heathrow Airport for the Europe/Mediterranean area and for the North Atlantic area. In effect the upper-air forecasting section at Heathrow has been transferred to CFO at Bracknell, but the final products continue to be issued by Heathrow. Preliminary results obtained during actual operational working indicate that the 10-level model is providing rather

more accurate navigational winds over the North Atlantic and Europe/Mediterranean regions than hitherto. It is also hoped that it may be possible to introduce into operational use forecasts which have a shorter validity time than those previously in use, by making use of the greatly increased speed of the new computer. This should also lead to an improvement in accuracy of forecasts used for flight documentation.

An IBM 2250 visual display unit is situated in the forecast room and this affords the forecaster a means whereby he can directly interrogate the main computer and feed in certain instructions which have a measure of control over the procedures which lead to the operational numerical forecasts. He can, for example, insert estimated values where real data may be sparse in order to achieve the correct analysis of the meteorological situation, or again he can display the observations stored in the computer, so that he can check their accuracy in case of doubt. This display unit is a recent acquisition and its full potential has not yet been fully realized. Work to this end is in progress.

A further innovation in the method of working in CFO has been the production of line-drawn charts by means of the Calcomp 1670 high-speed microfilm plotter, which is located in the computer laboratory. The film prepared on the plotter is enlarged and printed in CFO on an electrostatic type-printer, so that line-drawn charts are produced at the rate of about four a minute ready for transmission by facsimile.

This year, 1972, has thus been a notable one for innovation, but the main tasks imposed on CFO remain much as in recent years. The increasing use made of computer methods in performing these tasks makes it desirable briefly to describe the sequence of events used at Bracknell to produce forecasts for periods of up to 72 hours ahead at levels from the surface to a height of about 100 mb (16 200 m). The first requirement is of course observational data. The techniques for the production of such data were the subject of the Directorate of Services special topic in the *Annual Report on the Meteorological Office* for 1971. For operational forecasting by means of the octagonal version of the 10-level model, it is necessary to use data for most of the northern hemisphere. The data are acquired through various circuits of the Global Telecommunication System, which was described in one of the special topics for the 1969 *Report*. There are two primary hours of observation per day throughout the world, viz. midnight and midday, Greenwich Mean Time. The computer operates on the observations received for these times though, as a check, some reference may be made to observations at other times. The observations acquired by the Bracknell Meteorological Telecommunication Centre are read into the computer three hours after the two primary observation times, i.e. at 03 GMT and 15 GMT. Forecasts valid 24 hours ahead are available about 0415 GMT and 72 hours ahead at 0430 GMT. The observations received by 03 GMT and 15 GMT do not at present give the complete coverage of the hemisphere which is desirable. Consequently a second forecast run is made at about 1130 and 2330 GMT by which time coverage is as complete as the global observational network and telecommunications permit. This second run therefore incorporates all the data it is possible to obtain, whilst estimated values may be added and other manual adjustments may be made to ensure the best possible representation of the synoptic situation, both at the surface and in the free atmosphere up to the top of the forecasting model, i.e. 100 mb (16 200 m). Forecasts are made during these second runs to validity times of 12 hours ahead in order to produce most-probable analyses

or 'first-guess' analyses to which the observations at the next primary hour may be fitted, in order to produce objective analyses for that hour. The cycle then repeats.

Computer analyses and forecasts other than at the surface are issued in unmodified form on a number of facsimile land-line and radio circuits, both to domestic and to foreign recipients. Some modification is however often made during the production of flight documentation for civil aviation. This is usually confined to adjustments of the computed jet stream in the light of the most recent observational data available. Analyses at 50, 30 and 10 mb continue to be hand drawn, though programs are being written in order to obviate this.

The senior forecaster's primary task is to provide guidance to the outstations of the Office, mainly by means of charts depicting actual and forecast surface synoptic conditions augmented by advisory texts covering the next two or three days. CFO further assists the outstations by plotting hourly weather charts for the British Isles and three-hourly charts for the western European area. These are transmitted to them by land-line facsimile, thus eliminating the necessity for such charts to be plotted at outstations. The Calcomp microfilm system referred to above is capable of producing these charts very rapidly and sufficiently clearly for facsimile reproduction, but it would be imprudent to rely on a single equipment for round-the-clock working every day of the week. Plans have therefore been approved for the purchase of additional equipment which will relieve CFO of a very great deal of the hand-plotting of charts.

The advisory texts issued by the senior forecaster are augmented by telephone conferences with staff of some of the major outstations responsible for producing forecasts for all or some part of the United Kingdom. Such conferences are frequently held with the staff of London Weather Centre, which is responsible for extempore television and radio broadcasts for the whole country. Conferences are also held regularly with the staff of the offices at Gloucester and Prestwick in relation to the expected weather over Wales and Scotland respectively.

Another function of CFO is to provide routine forecasts for sea and land areas and to issue notifications of expected specified weather such as fine spells, or warnings of hazardous conditions. These are intended primarily for dissemination by the Press and radio, but some are issued direct to public utilities such as the Central Electricity Generating Board (CEGB) and to industry. The hazardous conditions for which warnings are issued include gales for land and sea areas, fog, snow, icy roads, thunderstorms, frost, thaw, strong upper winds and ice accumulation on ship superstructures. Notifications are also issued for expected periods of propitious weather such as fine-spell periods of three days for farmers.

CFO is also a Regional Meteorological Centre (RMC) within the framework of World Weather Watch (WWW). The latter is a concept, ratified by the Congress of the World Meteorological Organization (WMO), whereby the meteorologically more advanced nations assist the less advanced. This is achieved by the establishment of three World Meteorological Centres, at Washington, Moscow and Melbourne, and by a number of RMCs. CFO has undertaken to meet stated needs of various countries in Europe for certain regional forecasts. This it does by the preparation, for wireless-telegraphy and radio-facsimile transmission, of actual and forecast charts covering a large area of the North Atlantic Ocean, Europe and the Arctic.

Analyses and forecasts of wave heights and directions are produced as routine by computer for the North Atlantic area, for periods up to 48 hours ahead. These are broadcast as a WWW requirement for the benefit of other European maritime nations and of ships at sea. They are also the basis of the ship-routeing service provided by CFO, mentioned elsewhere.

Cloud photographs from the automatic picture transmission (APT) of the United States ESSA weather satellites have continued to be received by direct interception at Bracknell daily. They are a routine aid in the preparation of surface analyses over the North Atlantic and European areas. Interpretations of the pictures (nephanalyses) have been prepared for issue to outstations by land-line and radio-facsimile. These nephanalyses have been extended to include pictures from all the accessible orbits. They are of considerable value to the outstations in their day-to-day work in the briefing of aircrews. In addition some major forecasting outstations and one research outstation receive APT pictures direct from the Bracknell receiving station by telephone line. The APT unit in CFO is responsible for adding the geographical grid to the pictures and for transmitting it to these selected outstations, so that they can locate the cloud systems geographically.

The plotting and analysis of ice conditions in the northern hemisphere has continued and regular broadcasts are made to assist navigation in waters subject to sea ice, as well as to assist other meteorological services. During the polar spring and summer the APT pictures mentioned above are of considerable value in delineating the edges of the main icefields, though the resolution is insufficient to depict individual icebergs. The ice charts also show sea temperature isotherms. Separate charts of isotherms are also issued on a daily basis for coastal waters of the British Isles. The temperature data for these purposes are all processed by computer.

Preliminary studies have commenced preparatory to the production of pictorial representations of conditions in the upper-air layers above the North Atlantic Ocean.

Forecasts for a week ahead have continued on a regular basis, but although some success has been achieved it is not yet sufficient to warrant publication of the forecasts. Meanwhile the more promising lines of approach continue to be explored.

Forecasts for the Bracknell area for 24 hours are available on tape and may be obtained by dialling Bracknell 24124. This service continues to be used extensively.

The work on the analysis of meteorological fields by means of orthogonal functions has continued and has reached the stage when the use of such an analytical method is within reach operationally in a small way. So far there is no reason to believe that it would not be possible to develop a 4-dimensional system for incorporating satellite and aircraft observations which are not of course made at standard heights (pressure levels) or times. Use of the IBM 360/195 computer indicates that the consumption of computer time will not be excessive.

A subsection of CFO has been responsible for some years for the development of programs required for operational numerical forecasting. During the year this team of meteorologists has written the programs required operationally to obtain the basic data sets by extraction from the synoptic data bank, to analyse these data and to print out the forecast results in a variety of ways. These ways are subject to frequent changes as the operational requirements are

themselves subject to change. Much of the preliminary work required to bring the 10-level model up to operational status had been previously done, as reported in the *Annual Report* for 1971, but there has been a continuing necessity for modifications and alterations to output format, chart sequence, etc.

CFO remains responsible for the publication of the *Daily Weather Report* (*DWR*) with its *Overseas Supplement* and *Monthly Summary* and the *Daily Aerological Record* (*DAR*). The system of issuing correction slips introduced in 1971 has continued to be satisfactory. The production of the observational material for the *DWR* and *DAR* (as opposed to the charts) has been based on output from the KDF9 computer. This computer is however to be phased out, so plans have now been completed for production by means of the IBM 360/195 computer on 1 January 1973.

In the international field the Chief Forecasting Adviser served as a member of the Working Group on the Global Data Processing System (GDPS) and, as a member of the smaller Study Group, contributed to the preparation of the forthcoming Guide to the GDPS.

Services for industry, commerce and the general public

Forecasting services for industry, commerce and the general public are provided directly by the Weather Centres and a number of other forecasting offices whose primary responsibility is towards aviation, or indirectly through radio and television, the Press and the Post Office Corporation's automatic telephone weather service (ATWS).

The demand for weather information recovered in 1972, following the drop from 1970 to 1971, but, even so, was still running at a level below the 1970 peak. The slow recovery is believed to be the result of the relatively quiet weather for most of the year. Direct inquiries to all forecasting offices totalled 1 582 129 compared with 1 535 523 in 1971 and 1 633 478 in 1970. Table X gives a breakdown of these inquiries according to purpose. As in 1971, building and road transport took a smaller percentage of the total, a trend which can be attributed to the quiet weather and to the strike in the construction industry, while holidays and marine matters maintained their lead and reflected the growing interest in leisure pursuits, in particular, yachting.

The year saw a number of changes in the dissemination of forecasts over BBC Radio. The most important concerned the arrangements for Regional forecasts on Radio 4. For many years, the Regional forecasts, prepared by regional meteorological offices and containing local detail which it is not possible to include in a general forecast, have been a feature of the Radio 4 weather bulletins broadcast on both medium wave and VHF. However, on 2 September, there was a change in the organization of the BBC and Regional forecasts for England can now only be heard on the Radio 4 VHF transmissions. In an attempt to provide medium-wave listeners with some of the regional weather details to which they had long been accustomed, the BBC and the Office decided to expand the 'live' presentations from London Weather Centre to include more local detail than before, although the time restriction meant that the area covered by the forecast had to be restricted to England. It was realized that this compromise solution would not satisfy all listeners and might therefore require modification in the light of experience; to this end, discussions between the BBC and the Office are continuing. The Radio 4 Regional services in Scotland, Wales and Northern Ireland remained unchanged.

Other changes included the provision of additional scripted forecasts for broadcast on Radios 1, 2 and 3, the provision of brief weather reports and forecasts for major cities for use during the Radio 2 programme 'The Early Show' and the replacement of the Radio 4 scripted forecast at 0755 on Sundays by a 'live' presentation from London Weather Centre. The arrangements whereby warnings of certain road weather hazards are passed to the BBC Motoring Unit for broadcast on Radio 2 were extended to include warnings of heavy rain.

The supply of routine forecasts and warnings to the BBC local radio stations continued, although with the closure of Radio Durham the total number of stations served was reduced to 19. The 'live' broadcasts by meteorological staff over several of the local radio stations continued to be very popular and, in November, this method of presentation was extended to Radio Sheffield. Discussions were held with a number of potential commercial radio companies concerning the meteorological services which might be provided when commercial radio is introduced in 1973; there is every indication that commercial radio will provide a valuable outlet for up-to-the-minute meteorological advice to the public.

As far as television was concerned, the year was one of disappointment. No progress was made towards obtaining a mid-evening 'live' presentation on BBC 2, while on BBC 1 a further set-back was suffered in January when the early-evening Saturday presentation was cut from one minute to 30 seconds. In October, as a result of a rearrangement of BBC 1 programmes, the lunch-time weather presentation on Monday to Friday was divorced from the News and became part of a new magazine programme 'Pebble Mill at One'. No major changes were made in the services to independent television companies.

A number of broadcasts and interviews were given by members of the staff on radio and television; most of these dealt with past and current weather. The Office provided facilities for the filming of various aspects of its work by teams from the BBC and Southern Television.

Services to the Press continued on much the same basis as in previous years. As usual, many requests were received from the national and provincial Press for special interviews or comment on a variety of topics, a number of these requests being stimulated by the formal opening of the Richardson Wing by the Prime Minister.

Calls on the Post Office Corporation's automatic telephone weather service totalled 12 860 877 as against 11 554 411 in 1971, a somewhat disappointing year bearing in mind that the 1971 total was in any event depressed by the Post Office strike. However, there can be little doubt that a major contributing factor was the unusually quiet weather for most of the year. In May, an exploratory meeting was held with Post Office representatives to discuss the current state and future development of the service and follow-up action is now being taken. By local arrangement, forecasts were again provided in connection with a marine sports information service operated in the Swansea telephone area during the summer, and for a ski report service operated in the Edinburgh telephone area during the winter months; the latter service was reported to have been very successful during the 1971–72 winter when it attracted over 33 000 calls.

The specialized services provided by the Office, for which charges are made, continued in good demand. These services cover a wide range of activities, only a selection of which can be dealt with in this report. The winter service of

'warnings of certain road dangers due to weather' to local authorities and others attracted 422 registrations for the full service and 35 registrations for a limited service, as against 416 and 46 registrations respectively in 1971. The demand for the 'notification of fine weather spells' declined yet again in 1972, following the trend of the past few years. The decline is undoubtedly due to the ready availability of weather information for two or three days ahead on public information channels, but it is nevertheless gratifying that 223 farmers and others considered the service sufficiently worth while to warrant registration in 1972. The popular services for pigeon racing again achieved an all-time record, 1409 'line-of-flight' forecasts being issued during the racing season to 107 pigeon organizations. In September, a meeting was held with representatives of the main pigeon organizations to discuss mutual problems and suggestions for improvements in the service.

Routine services for the gas and electricity industries, British Rail, London Transport, the North Sea oil and gas exploration and production industries and many smaller concerns continued as before, and renewed efforts were made to encourage all other weather-sensitive casual users of meteorological services to register for a routine service.

The Weather Centres at London, Glasgow, Manchester, Newcastle and Southampton and the public service office at Watnall continued to handle the bulk of the work in the public sector. Excluding weather maps provided for shipping at certain major ports, the total numbers of inquiries dealt with over the past three years are shown below:

	London	Glasgow	Manchester	Southampton	Newcastle	Watnall
1970	335 153	101 549	115 776	95 961	72 603	59 922
1971	303 695	91 430	107 228	79 976	82 654	62 728
1972	313 024	89 770	116 914	93 532	81 889	57 483

Grand totals: 1970, 780 964; 1971, 727 711; 1972, 752 612

With a view to easing the load of casual telephone inquiries, which become almost unmanageable during periods of bad weather, a trial was carried out at the Newcastle and Southampton offices during which an inquirer, having been given an answer to his question, was advised of the forecasts available on the Post Office automatic telephone weather service, in the hope that the inquirer would use the latter service in the future. Preliminary results suggested that this action had had a negligible impact on calls to the offices in question and it appeared that most inquirers taking advantage of the personal service do so because they are seeking discussion of their problems, or wish to put supplementary questions the answer to which cannot be obtained from a recorded forecast.

The general public continued to show a lively interest in the work of the Office in general, and that of the Weather Centres in particular, and an increased number of requests was received for visits to the various offices and for talks to be given to outside bodies. The staff of London Weather Centre alone gave over 150 lectures and talks during the course of the year, while 35 parties visited the Centre and were shown the work of the office. At Headquarters, the opening of the Richardson Wing with its new and sophisticated installations

excited considerable interest, and the number of organized visits by parties of the general public reached an all-time record of 61, while a further 22 visits were arranged for representatives of the Press and various broadcasting organizations.

Although the past two years have seen a hesitation in the growth in demand for weather information, the evidence suggests that the growth will soon be resumed and bring with it new problems for the Office in the provision of services to meet all needs.

The Office is constantly reviewing its arrangements for meeting its responsibilities for keeping the general public informed about the weather and for dealing with the specialized needs of industry and public bodies for meteorological advice. A firm of consultants was commissioned to assist in the review and their report, received early in the year, made a number of recommendations on the scope of existing services, the possibilities for extending the range of specialized services and on promotional and charging methods for these services.

A departmental committee, which had acted as a steering group during the consultancy study, has been examining these recommendations and has prepared an outline plan dealing with the dissemination of weather advice to the community, through the mass-communication channels, and with the provision of detailed advice to industrial and commercial interests.

Services for marine activities

Expanding offshore drilling activities during the year led to an increasing demand for meteorological services provided by London Weather Centre. This activity is very weather-sensitive and most operators contract to receive routine forecasts for each individual rig, barge or structure under their control. Forecasts were also provided by CFO for the oil drilling ship *Glomar North Sea* operating off southern Ireland for much of the year, and for a number of oil drilling rigs in tow from Europe to West Africa. The Meteorological Office at Plymouth/Mount Batten provided special forecasts for very large oil tankers discharging part of their cargo to smaller vessels when at anchor in Torbay.

Following discussions with the Department of Trade and Industry (DTI) and the BBC the title of the late-night Coastal Waters Forecast on Radio 4 was changed to 'Forecasts for Inshore Waters' and the area of coverage of the forecast was standardized at up to 12 miles offshore. At the request of the DTI revisions were made in the arrangements for the issue of meteorological advice in a marine pollution emergency.

During the summer months several meteorological offices met an increasing demand for information on actual and future weather conditions expected in coastal and inland waters.

Forecasts for Royal Navy ships were supplied by Pitreavie and Plymouth/Mount Batten offices, and for Royal Air Force marine craft at home and abroad by the nearest meteorological office. Advice was given by CFO to the Royal Navy officers accommodated at Bracknell who are responsible for issuing alerts in relation to the possibilities of flooding on the east coast due to the effect of strong winds which reinforce the normal tidal effects. Regular forecasts of wind and weather in certain northern coastal areas were issued to Geophysical Services International Ltd, and warnings of tropical hurricanes, cyclones and typhoons were issued to Lloyd's when appropriate.

During September, in response to a request from the Fisheries Division of the Ministry of Agriculture, Fisheries and Food for weather forecasts to be supplied from trawler support ships stationed off north and north-west Iceland during the period of the fishing limits dispute with Iceland, the Meteorological Office resumed the winter service previously commenced each December. This service consists of a regular supply of weather information, forecasts and gale and ice warnings transmitted from CFO Bracknell to a forecaster on board the trawler support ship stationed off Iceland. The forecaster maintains close touch with the British fishing fleet in the area, issuing regular forecasts and warnings twice daily, and more frequently when required.

Ship routeing services were provided for both the North Atlantic and North Pacific Oceans, the latter being a new service inaugurated in October. About 20 ships have so far made use of the North Pacific service; 250 ships were routed across the North Atlantic during the year. In general the aim of the routeing service is to provide shipmasters with advisory routes and courses to steer so that the time on passage will be minimal, commensurate with the avoidance of wave conditions liable to cause damage to the ship or cargo. The speed of the ship is calculated along various possible tracks in relation to the predicted wave-fields, and some regard is also given to the general conditions in the outlook period beyond 48 hours ahead. The main features of the general atmospheric circulation are also taken into account in arriving at the advice to be given to masters, particularly in the Pacific, where voyages usually last about 3 weeks. A number of other factors, such as the likelihood of fog or ice and the direction and speed of ocean currents are also taken into account.

The shipping forecasts broadcast four times a day by the BBC and the gale warnings prefixed 'attention all shipping' originate at CFO and are of course very well known. But there are a number of lesser-known services which CFO provides for marine activities. These included in 1972 the provision of a special daily forecast for the *Observer* Single-handed Transatlantic Yacht Race, as well as for the eastern portion of a race from Bermuda to Bayona, at the request of the United States National Weather Service. The capability exists for the forecasting of the movement of oil slicks, but this service was not called for during 1972.

At the request of Trinity House, and with the agreement of the BBC, reports from the Varne light-vessel were included in the shipping bulletins broadcast on Radio 2. The Main Meteorological Office at Pitreavie continued to supply during the winter months a special forecast service for the benefit of Scottish seiners and small trawlers operating in the North Sea.

Services for the general public (overseas)

The demand for answering general inquiries and for services to the local Press, radio and television continued to be met by the forecasting offices in Gibraltar, Malta and Cyprus. Special services were again provided during the year for oil-drilling rigs operating in Maltese waters and for warnings of tropical storms near the coast of Oman.

Services for civil aviation

Forecasting services for civil aviation in the United Kingdom, formerly provided by the Meteorological Office as the agent of the Department of Trade

and Industry (Civil Aviation), have been provided on behalf of the new Civil Aviation Authority (CAA) since 1 April 1972.

The Principal Forecasting Office at London/Heathrow Airport remains the designated European Area Forecast Centre for all flights to the U.S.A., Canada and parts of the Caribbean from European terminals and controls the dissemination of all transatlantic forecast charts by land-line facsimile to Dublin, Paris, Frankfurt, De Bilt and Copenhagen and also by radio-facsimile broadcast to the more distant parts of the European area.

Additionally the Principal Forecasting Office at Heathrow acts as the hub of the Civil Aviation Facsimile Network (CAMFAX) serving 14 major civil airports throughout the United Kingdom. For all flights above 5000 ft ($\approx$ 1500 m) forecast charts relating to en-route weather conditions, upper winds and temperatures are issued at 6-hourly intervals as routine. These cover the two main areas of operation—the whole of Europe including the Mediterranean, and the North Atlantic.

A major part of the basic technical work at the Principal Forecasting Office at London/Heathrow Airport was transferred to CFO at Bracknell early in November 1972 with the setting up of a special civil aviation unit responsible for the preparation of forecast upper wind and temperature charts required by civil aviation from data processed by the IBM 360/195 computer. These charts are transmitted to Heathrow by facsimile. Charts depicting weather likely to affect the safety of aircraft in flight are prepared locally at Heathrow.

Meteorological services for general aviation (private pilots, flying clubs, air taxi services, etc.) are provided by local civil aviation and RAF meteorological offices on request. For flights in this category below 5000 ft special flight forecasts are prepared giving more details of cloud, visibility and other phenomena which may be hazardous to light aircraft—details not required for flights at much higher levels by the major airline operators. In order to improve the meteorological service provided to this rapidly growing branch of civil aviation an operational trial of a new answer-phone service commenced on 1 December 1972. Forecasts for 21 areas covering England and Wales and the near Continent are provided in an abbreviated format by the Main Meteorological Offices at Preston and West Drayton and are tape-recorded at dictation speed. Pilots may receive these forecasts by telephoning discrete numbers at Preston or West Drayton.

BOAC has continued to operate its computerized flight-planning service for flights across the Atlantic both westbound and eastbound. The meteorological forecast data required, comprising upper winds and temperatures in a grid-point format at about 35 000 ft ($\approx$ 11 000 m) are supplied by telex to BOAC at Heathrow from the Bracknell computer twice daily for validity times 00, 06, 12 and 18 GMT. Following installation of the new IBM computer at Bracknell it became possible to provide a more comprehensive coverage of the Caribbean area; the service to BOAC was extended accordingly with effect from 4 December 1972. A similar service to the Air Traffic Control Evaluation Unit at Prestwick was also extended in April when forecast data, previously provided once daily, began to be issued twice daily.

The Principal Forecasting Office at Heathrow, through the Concorde forecasting unit at Fairford, Gloucestershire, has provided special forecasts for Concorde 002 and 01 test flying including the forecast for the initial subsonic stage London–Athens of the flight of Concorde 002 to Singapore, Japan and Australia in June 1972.

New procedures for the provision of meteorological services for Royal Flights in RAF aircraft were introduced on 1 January 1972. These include the provision of flight forecast documentation in accordance with standard International Civil Aviation Organization (ICAO) operational procedures at home and overseas and a special meteorological service in support of improved en-route air traffic control services for Royal and Selected Flights by helicopters in England and Wales.

The seventh ICAO Conference on Joint Financing of the North Atlantic Ocean Stations (NAOS) was held at the ICAO Headquarters in Paris in March 1972 to consider the future control and operation of ocean weather ships. Information relating to the usefulness of the data provided by these ships in the preparation of aviation forecasts was submitted by the United Kingdom delegation. The meeting decided to extend the operation of these ships until 1975; the future of the NAOS scheme will be determined at a full conference in 1974.

Services for the Royal Air Force

Forecasting services continue to be provided for the Royal Air Force by stations distributed largely in conformity with the RAF organization. There is a Principal Forecasting Office at Headquarters Strike Command, and Main Meteorological Offices, functioning throughout the 24 hours, are located at convenient centres to control and advise subsidiary offices and enable them to meet the various requirements of aircraft of many types operating in many different roles. At subsidiary stations, a forecaster is on duty at times depending on the requirements of the RAF.

A senior officer of the Meteorological Office is located at the respective RAF Command Headquarters. This officer acts as adviser in meteorological matters to the Air Officer Commanding-in-Chief and as liaison officer between him and the Director-General of the Meteorological Office.

Maximum use is made of the technical support provided centrally by the Bracknell Central Forecasting Office and the IBM 360/195 computer. At Headquarters Strike Command and 46 Group a comprehensive 6-hourly routine of area and route forecasts in chart form is prepared, to meet the majority of operational requirements. These routine issues include a forecast surface-analysis and a significant-weather chart in addition to upper-air forecasts at standard levels. The charts are distributed by land-line facsimile to subsidiary offices where they are duplicated for issue to aircrews at pre-flight meteorological briefings.

With the establishment of mobile meteorological units within Strike Command, meteorological support is given to RAF elements participating in field exercises in the U.K. and overseas. Each unit has its own air-transportable meteorological and communication equipment for use at locations far removed from permanent meteorological offices. The facilities include radio-teleprinter, radio-facsimile recording equipment and apparatus for receiving satellite cloud pictures. Forecasters in the mobile units hold commissions in class C.C. of the Royal Air Force Reserve of Officers. For dealing with the forecasting problems which arise in this type of operation, special techniques have been evolved and these are available in a booklet compiled by the Principal Meteorological Officer of the unit, who regularly keeps the techniques under review.

Meteorological officers continue to give regular courses of meteorological instruction at a number of schools in Training Command and at Operational Conversion Units. Further studies were made of the suitability of meteorology as a subject for programmed instruction at the schools. The RAF has established a team to prepare a training package and a meteorological officer has been attached to the team to act as adviser.

A runway visual range system, based on a count of reference lights visible to an observer positioned near the runway touch-down points, is in the process of being introduced at about 50 RAF aerodromes. The Meteorological Office continues to co-operate by providing technical advice and calibrating the lights after they have been installed. Each system is also checked and recalibrated every six months.

A Military VOLMET broadcast of plain-language weather reports for major RAF aerodromes in the United Kingdom was started in March. This broadcast is designed, in the main, to meet the requirements of transport aircraft returning from overseas.

Overseas, in the Federal Republic of Germany, the Mediterranean, the Middle East and the Indian Ocean, services provided for the Royal Air Force follow the same general lines as in the United Kingdom. A Main Meteorological Office at Rheindahlen caters for RAF flying in Germany and similar forecasting offices at Gibraltar, Malta, Episkopi (Cyprus) and Gan (Maldives) cover Royal Air Force requirements in the Eastern Atlantic, the Mediterranean, through to the Indian Ocean and eastwards to Singapore, Hong Kong and Australia. These Main Meteorological Offices are augmented by subsidiary forecasting offices in Germany and Cyprus and by the new subsidiary forecasting office at Masirah (Oman).

The Episkopi Main Meteorological Office is the largest British forecasting centre outside the U.K. and, as in the U.K., maximum use is made of the technical output supplied by the Bracknell Central Forecasting Office and the IBM 360/195 computer. In turn, Episkopi provides strong technical support in the Mediterranean and Middle East areas through the radio-teletype and facsimile broadcasts of basic data and forecast charts.

At Gan and Episkopi, stations for receiving cloud photographs by automatic picture transmission (APT) from the U.S. ESSA satellites have proved invaluable in recent years, particularly in supplying information from over the oceans and unpopulated areas where observations are scanty. Four further APT receiving stations—at Masirah, Gibraltar, Malta and Rheindahlen—had become operational by the end of the year and will prove valuable forecasting aids.

In Malta many problems concerning the operation and organization of meteorological services were experienced during the political negotiations for a new Defence Agreement.

Services for Army and for Experimental Establishments

A meteorological office maintained at the Royal School of Artillery, Larkhill, on Salisbury Plain, provided ballistic information, advice on the training of the Royal Artillery Meteorological Section and other meteorological assistance to Army units throughout the Salisbury Plain area and to the Royal Aircraft Establishment (RAE) at its trials site. A special feature of the Army work during the year continued to be the assessment of noise nuisance to the general public.

A review of services provided for the Army Aviation Units based on Salisbury Plain resulted in the opening of a subsidiary forecasting office at Netheravon and it is planned to open a similar office at Middle Wallop during 1973.

An office on the establishment at Aberporth supplied the needs of the RAE there, and three offices were maintained at Proof and Experimental Establishments to provide meteorological advice for trials.

The Army Meteorological System (AMETS) for the automated measurement and processing of upper-air data for ballistic purposes reached the trials stage.

Liaison with the Navy Department

Close co-operation has continued with the Director of Meteorology and Oceanographic Services (Naval) on all aspects of the co-ordination of plans to meet the meteorological requirements of the defence forces both at home and overseas.

International defence services

The United Kingdom is represented on the various meteorological planning committees of the international defence organizations NATO, CENTO and SEATO. These committees have the task of co-ordinating the meteorological support required by the military forces and, as necessary, of studying the meteorological problems involved. The twenty-ninth meeting of the NATO Military Committee Meteorological Group took place in Brussels in June. The U.K. member was Mr P. J. Meade, Director of Services, and he was accompanied by Mr E. Evans and Mr D. W. Tann. During the year there were again two meetings of the NATO Military Committee Meteorological Group's Working Groups on Weather Plans and Weather Communications. These meetings were held in Athens and London.

The CENTO Regional Meteorological Advisory Group met in Ankara in October. Messrs G. Thornton-Smith and D. W. Tann were the U.K. delegates.

The Tripartite Technical Co-operation Programme Panel N-6 (on nuclear fallout) met in London in December.

Services to the Home Office

The meteorological requirements of the Warning and Monitoring Branch of the Home Office have been kept under review and detailed plans for meeting these requirements as effectively as possible in an emergency are maintained and tested in exercises. Lectures were given to Home Office Sector Scientists and to members of the Royal Observer Corps (now part of the Warning and Monitoring organization) who are equipped and trained to make simple meteorological observations in times of emergency.

Services for nuclear establishments

To meet the national requirement for meteorological information under the arrangements to deal with the accidental release of radioactive or toxic material, six Main Meteorological Offices provide information to nuclear establishments. These arrangements are tested, without notice, twice a year with the establishments concerned, which are operated by the United Kingdom Atomic Energy Authority, the Central Electricity Generating Board and the South of Scotland Electricity Board.

Climatological Services

The main function of the Branch is to provide information and advice about climate. The foundation of the service is a network of about 650 observing stations of various types. The majority of these stations are manned by voluntary observers and the Office takes this opportunity to thank them for their excellent co-operation. The Branch is responsible for the inspection of the network and for the collection, quality control, publication and preservation of surface and upper-air observations made at stations in the United Kingdom. The surface observations are published in the *Monthly Weather Report* (*MWR*) and its *Annual Summary* and in other non-routine climatological publications. About one in five of the stations in the network make returns of climatological observations at more than one hour per day and these data have been subject to quality control by computer methods for some years. During 1972 considerable effort was put into the development of methods of computer quality control of data from the other stations which make climatological observations only once each day. Work continued on the preparation of programs to enable the whole *MWR* to be produced by computer.

Developments in the application of climatology in many fields continued. One item of special interest in 1972 concerned the assessment of fog probability on alternative routes of proposed roads and advice was given on the probable effects on humidity and fog frequency of the construction of large artificial lakes. Further investigational work was done on the occurrence of glazed frost over northern England in March 1969 which resulted in the collapse of the Emley Moor television mast.

The general trend for increasing numbers of climatological inquiries, though checked last year, has now been re-established; about 12 per cent more inquiries were received in 1972 than in 1971. As usual the inquiries covered a wide range and included many legal questions concerning past weather, requests for climatological data in connection with the design requirements and siting of buildings and structures and for climatological data relevant to the sales of commercial products and the transport and storage of materials. Amongst the more unusual inquiries was one for data on the magnitude of horizontal temperature gradients at 100 and 200 feet which are thought to affect the performance of racing pigeons.

While most requests are for information relating to the United Kingdom, the Office is also prepared to answer inquiries about the climate of any other country. Data to meet this requirement are usually collected by means of an international exchange of processed material but there are also some data for British-operated stations overseas. Examples of these inquiries are: for extreme wind speeds in different parts of the world (often where only very scanty data are available) in connection with building design; for locations in North America where earth temperatures are within the range suitable for a material used for surfacing sports grounds; for data for the compilation of an atlas of upper winds in the southern hemisphere; for data of snow and icy weather in parts of Europe in order to plan the production of winter tyres.

The Office continued to collaborate with government or government-associated agencies such as the Building Research Station, the Transport and Road Research Laboratory and the British Standards Institution (BSI). A senior officer served on the BSI Committee which completed a revision of the Code of Practice concerned with the Wind Loading of Buildings. Investigatory

work was also performed for the BSI Committee producing a Code of Practice for the Wind Loading of Bridges. The Office was represented on a Technical Panel convened by the Royal Aeronautical Society to produce guidance notes on the behaviour of the wind in the lower layers of the atmosphere for engineering and design applications.

Climatological services for Scotland and Northern Ireland are provided by offices in Edinburgh and Belfast respectively. The Superintendent of the Edinburgh Office served on two working parties of the Scottish Development Department dealing respectively with the requirements for climatological data in Scotland and with storm sewerage and he also continued to serve as Adviser to the Clean Air Council for Scotland. The morale of the staff of the Belfast Office continued high in spite of the numerous alerts, and actual damage sustained to the building by a bomb explosion in July.

In the marine climatology section work continued on the preparation of the annual publication *Marine climatological summaries for the Atlantic Ocean east of* 50° *W and north of* 20° *N*, published by the Office by international agreement. The second volume, that for 1965, is in print and work is on hand on the 1963 and 1966 volumes.

Monthly charts showing the distribution of sea ice at the end of each month were issued as usual. Work continued on the task of checking, preparing for punching and supervising the quality control of ocean current data in respect of recent observations and of the backlog of data prior to 1929. The ocean-current and, where applicable, the sea-ice sections of six volumes of Admiralty *Pilots* were revised. The chapters dealing with ocean currents in the *Marine observer's handbook* and *Meteorology for mariners* were rewritten and a new article on sea ice was prepared for *The mariner's handbook*. Inquiries relating to marine climatology, ocean currents and sea ice were dealt with, among them being one in which a firm of nautical advisers required an opinion on the degree of abnormality of a specified sequence of rough weather experienced on an Atlantic crossing, and another which concerned the seasonal variation of extreme wind speeds in the northern North Sea in connection with the possible restriction of the use of certain existing offshore drilling rigs in these waters to the less stormy months of the year.

The marine climatologist remained a member of the Working Group on Marine Climatology of the Commission for Marine Meteorology (CMM) of WMO, and chaired a meeting of the Group's Polar Panel held in Geneva in April. He represented WMO at two international meetings held in London, in February at the Inter-Governmental Maritime Consultative Organization Sub-committee on the Safety of Fishing Vessels and in October on the Convention on the Dumping of Wastes at Sea. Early in the year he was nominated as CMM rapporteur on the meteorological aspects of icing on superstructures of ships and also as Office representative on the Natural Environment Research Council Working Party on Climatology, which met four times during the year. He continued to attend monthly meetings of the Offshore Installations Technical Advisory Committee of the Department of Trade and Industry and made further contributions to a joint paper on environmental conditions relating to the design and use of installations, which is to be issued as part of the Committee's Guidance Notes for Construction and Survey Regulations, prepared in accordance with the Mineral Workings (Offshore Installations) Act, 1971. Other work included further studies, in collaboration with the National

Institute of Oceanography, of relationships between wave heights and wind speeds in U.K. coastal waters.

Hydrometeorology

The hydrometeorological work of the Office falls naturally into three sections: routine, inquiries and investigations. The routine covers regular collection, scrutiny, processing and preservation of rainfall data from some 6900 stations in the U.K. Most of the data are collected from voluntary co-operating stations maintained by private individuals, water supply undertakings, local authorities and river authorities. Regular inspections are made to ensure the maintenance of required standards of site, instrumentation and observational procedures, and 757 stations were visited during the year. The Edinburgh Office administers and inspects stations in Scotland, handles their data and deals with local inquiries, whilst the Belfast Office has similar responsibilities for Northern Ireland. Rainfall data are published in the *Monthly Weather Report* and in *British Rainfall*, and from time to time in non-routine publications and branch memoranda. In particular the year saw the completion of the texts of *British Rainfall* for 1968 and the second five-year supplement to *British Rainfall*, viz. that for the period 1966–70, and good progress has been made on the 1969 and 1970 volumes of *British Rainfall.*

Work has begun on the scrutiny of evaporation* data being collected, prior to the introduction of routine processing and quality control of the data on lines similar to those for rainfall data. This development follows investigational work in the inquiries section, firstly on the problems of siting and observational practice in the use of evaporation tanks, and secondly on the apparent and potential accuracy of the irrigated lysimeters maintained by the Nature Conservancy

The inquiries section has continued to answer a wide variety of hydrometeorological inquiries, the volume of work being much the same as in 1971. Routine services and methods of answering general inquiries are being improved by taking advantage of the new computer facilities now available in the Office.

Several major inquiries were handled during the year, most of them for the Thames Conservancy and the Water Resources Board. Work for the Conservancy included the estimation of daily rainfall and monthly potential evaporation for 1970 over 25 aquifers in the Thames valley and similar work for areas in the Pang catchment, the Cotswolds and the Berkshire Downs for periods of many years as a contribution to the Conservancy's groundwater development. For the Water Resources Board estimates of monthly rainfall in the period from October 1967 to September 1968 were supplied for all areas (several hundred) for which data are customarily published in the *Surface Water Year Book* and estimates of weekly rainfall and potential evaporation 1966–70 for 10 areas in Great Britain for publication in the revised format of the *Surface Water Year Book.* Work continued on the routine estimation of monthly rainfall for about 460 catchment areas for the Surface Water Survey. The practice of river authorities asking for data in advance of publication of the *Year Book* has increased, and many authorities now receive estimates of areal rainfall and station evaporation as a routine service. The Water Resources Board also had

*Where appropriate 'evaporation' should be taken to include 'transpiration'.

estimates of monthly rainfall, potential and actual evaporation and soil moisture deficit for 13 regions in England for publication in the *Groundwater Year Book* 1968–70. The number of areas for which assessments of areal rainfall are required is continually increasing as the river authorities develop their networks of river-flow gauging stations and the authorities have also been given advice on rain-gauge networks. Estimates of average annual rainfall have been made for some 200 catchment areas for the Flood Studies team at the Institute of Hydrology. Estimates of areal rainfall on certain dates in 1938, 1954 and 1964 over the Cocker and Derwent catchments were made, and estimates of the return periods made as a contribution to a flood warning scheme for Cockermouth.

The inquiries section continues to be responsible for estimating evaporation for a network of stations and for investigations of evaporation problems and continues to issue the bulletin *Estimated Soil Moisture Deficit and Potential Evapo-transpiration over Great Britain.* The availability of the IBM 360/195 computer and the potential use of the computer bank of daily meteorological data from synoptic stations have encouraged the development of new models for estimating evaporation and soil moisture deficits, and the aim is to issue the bulletin weekly. In the new system air temperature and vapour pressure will be estimated for a set of squares of area 40 × 40 km covering Great Britain. With the assistance of river authorities estimates of land use for the same squares will be made and it is hoped to obtain similar assessments for Scotland; from these will be derived estimates of grid-square average albedo. A new method of estimating area-representative, seven-day average low-level wind speeds has also been developed.

Further progress has been made in assessing end-of-month soil moisture deficits for each month in the period 1941–70. These are now complete for a good network of stations in England and Wales. The Institute of Hydrology has used these estimates in flood study work. Basic work for the assessment of soil moisture deficits for Scottish stations for the period 1961–70 has been completed and a start has been made on the analysis of these results.

A map of average annual duration of rainfall over the United Kingdom for the period 1941–70 has been produced, and considerable progress has been made on the preparation of an average annual rainfall map for the same period, using computer methods for the first time. The latter will be a follow-up to the standard map for 1916–50 and is based on decadal values which will allow easy updating in the years to come. Preliminary work has been carried out on the production of a map of average annual potential evaporation for 1941–70.

With the co-operation of river authorities the network of stations in England and Wales for estimating the water equivalent of lying snow is being increased, and new procedures for estimating areal values are being introduced in the winter of 1972–73. A knowledge of these values is important in forecasting river flow levels during periods of thaw. The Office is examining objective methods of forecasting snowmelt as a possible contribution to the work of river authorities in their river flow forecasting.

The investigations section has been active in several fields. Work on new quality control programs for daily rainfall data has progressed steadily towards the operational date of January 1973. The new routines replace the former spatial quality control and, in addition to flagging errors, they provide suggested amendments. The practice of dividing the country into computer areas and using an area mean for error checking is no longer necessary, as a countrywide

comparison of each station with its eight nearest neighbours is now possible, using IBM 360/195. The new programs, together with much improved data-entry systems, should result in better quality control.

A description of the scope of the comprehensive areal rainfall program (CARP) was given in a paper presented at an international symposium. In particular the paper showed that for most parts of the United Kingdom the minimum area for which the program in its present form using a 5-km grid can produce acceptably consistent areal rainfall values is 200 km^2.

Two important developments took place during the year regarding close time-scale detail from rain recorders. First, the field trials of magnetic-tape rain recorders reached a very promising stage and operational assessment of the equipment with appreciably augmented station networks is planned for 1973; these magnetic tape recorders provide ready translation of the detailed data into computer magnetic tape for analysis and archiving. Secondly, a programme of work was started to transfer the data obtained by conventional rain recorders (traces on paper charts) to digital information on magnetic tape, using the Precision Encoding and Pattern Recognition (PEPR) equipment at the Nuclear Physics Laboratory, Oxford. The vast majority of past data from rain recorders have never been adequately analysed because of the great effort which would be involved; with PEPR it is expected that about two million daily charts will be dealt with in about three years, which will provide a large and detailed archive of accumulated past data in readily usable form.

The Dee Weather Radar Project, a joint study by the Office, the Water Resources Board, the Dee and Clwyd River Authority and Plessey Radar Limited to investigate the feasibility of using weather radar to measure precipitation, made good progress toward the research objectives. Radar measurements of precipitation over the Dee catchment were recorded on magnetic tape as a routine and analysed at Bracknell by the research team of seven scientists. One of the main objectives of the Project is to measure rainfall on a space- and time-scale appropriate to hydrological requirements and to meet this objective the radar rainfall estimates have been computed hourly over subcatchments of size 20 km^2 or greater. With the present radar system measurements can be made to a range of 50 km. These values have then been compared with the independent estimates derived from the network of 60 recording raingauges which are distributed over the 1000-km^2 catchment and operated by the Dee and Clwyd River Authority and the Office. Results to date show that the difference between the gauge network and radar estimates of hourly rainfall over the subcatchments is on average about 20 per cent, decreasing to about 10 per cent as the area size is increased up to about 500 km^2. Part of the difference, typically 5–10 per cent, can be attributed to errors in the gauge estimates of areal rainfall. In localized showers the radar is greatly superior to the gauge network in identifying positions of rainfall maxima. The accuracy of the radar estimates is much reduced when the radar beam intersects the melting layer, a common occurrence in North Wales in winter. One of the most important of the tasks still under investigation is to determine whether correction techniques can be devised which will improve accuracy in these circumstances. The radar is also capable of measuring snowfall, and a network of about 200 schoolboys has been organized to measure snow depth so as to provide an independent measure with which the radar estimates can be compared. However, very little snow fell over the area during the year.

Work has continued on the meteorological aspects of the United Kingdom Flood Studies, and the team will complete its tasks on schedule at the end of March 1973. A great deal of the effort has been devoted to assembling the necessary minimum amount of data: observations from 500 long-period (50–100 years) daily stations scrutinized and computer banked; heavy falls for short durations for 100–150 recording rain-gauge stations (mostly 20 years' data) extracted manually from charts and manuscript tabulations of hourly rainfall. The main analytical effort has been devoted to developing numerical models from which estimates could be made with reasonable accuracy:

(a) Point rainfall to be expected at any place in the United Kingdom for any duration from a few minutes to several days, and with return periods up to 100 years.

(b) Reasonable extension of (a) above to higher return periods, with estimates of the probable maximum falls in given durations.

(c) Areal factors to be applied to (a) and (b) to give estimates of areal rainfall for given durations and return periods, for areas up to 10 000 km^2.

(d) Some indication of the variation of profiles of heavy storms, of given duration, about their peak intensity.

(e) As far as possible, to give estimates of seasonal variation of (a) to (d).

(f) To provide estimates of maximum snowmelt rates.

It was regarded as very important that the material should be condensed into a small number of maps and tables, together with clear instructions, from which any competent user could derive objective estimates.

Co-operation has been maintained with the team of hydrologists working at the Institute of Hydrology on the hydrological aspects of the Flood Studies Project and numerous inquiries in this field from other sources have been answered throughout the year.

The Senior Scientific Officer attached to the Institute of Hydrology has continued his research work on evaporation from forests. A knowledge of evaporation is important for predicting the water resources of an area and in irrigation planning. The Monteith form of the Penman equation is used in predicting evaporation from a forested area and this demands measurement or estimation of the surface (or stomatal) and aerodynamic resistances. The latter can be estimated from measurements of wind speed and the physical dimensions of the trees. The Thetford Project has been set up to determine the relationship between the surface resistance of the forest and the evaporation rate, soil moisture deficit, light intensity and other factors. The second component of the total evaporation from a forest is that which occurs when the forest is wet after precipitation. In this case the process is much simpler since it is controlled only by the meteorological conditions. However, it is not easy to predict, because the rate of evaporation then depends very strongly on the vapour pressure deficit, which is itself affected by the rate of evaporation, the available energy and the aerodynamic resistance. This feedback mechanism is also under investigation as part of the Thetford Project. A further wealth of data was obtained during the year, considerable progress was made in the analysis of data, and several scientific papers were drafted.

The Office has been involved in discussions on the proposed reorganization of water management in this country and has continued its contribution to

international hydrometeorology through co-operation with WMO and Unesco. Members of staff serve on working groups of WMO's Commission for Hydrometeorology and the Office is represented on the British National Committee of the International Hydrological Decade.

Services for Agriculture

The pattern of services for agriculture has shown little change in the past year. A new service was the weekly supply of soil moisture deficits and soil temperature anomalies to London Weather Centre as background material for farmers' forecasts on BBC Radio. The effort of the staff at Headquarters was mainly devoted to the advancement of the science of agricultural meteorology. Nevertheless, a significant fraction of the total effort was used to support the work of the outstations mainly by the extraction and computer processing of data for their use. Liaison Officers at Bristol, Cambridge, Leeds and Edinburgh continued their own lines of investigation as well as maintaining their advisory roles with other disciplines within the Agricultural Development and Advisory Service and the provision of advice to the farming community. Because of the increasing level of work demanded the post at Leeds was upgraded during the year.

The problems of land drainage continued to present a challenge and a new system was devised for the analysis of dry spells in spring. The analysis was made for varying standards of drainage and differing work schedules. The study has produced means of estimating the increased productivity of cereals and vegetables that could be achieved in each region and for each existing standard either by improving land drainage or by increasing mechanization. Similar studies have been made on the effect of weather on the number of available work-days in spring and autumn particularly as this affects the time of sowing. Other studies of the influence of weather in economic decision-making included the regional variation of hours available for combining.

A report on the Climate of Scotland was produced for subcommittee 'A' of the Select Committee on Scottish Affairs. A study was begun on the climatic restraints to plant production in higher-latitude mountain areas in connection with a study group of the International Society of Biometeorology. Climatological data from upland stations were analysed mainly in respect of the potential of upland areas for grazing. Co-operation with the Soil Survey of England and Wales continued throughout the year and chapters on climate were written for inclusion in the *Soil Survey Records* for Ashford (Kent), Deal, Marlow-on-Thames and Burnham-on-Crouch.

Participation in international affairs in Agricultural Meteorology, whilst not reaching the heights of previous years, continued to demand a substantial effort. Mr L. P. Smith edited a WMO *Technical Note* on 'The application of micrometeorology to agricultural problems' and Mr C. V. Smith's *Technical Note* 'Some environmental problems of livestock housing' was published. One member of staff was appointed chairman of the Working Group of the Commission for Agricultural Meteorology on 'Meteorological factors concerning certain aspects of soil deterioration and erosion'. Another member is acting as rapporteur to the same commission on 'The effect of soil mulches on temperature'. The chairman was provided for the Steering Group on 'Climatic restraints to plant production in higher latitude maritime areas' which met at Leiden,

The Netherlands, during the 6th International Congress of the International Society of Biometeorology.

Lectures were given to various agricultural bodies, colleges and associations. Published papers numbered 17 during the year and 90 *Agricultural Memoranda* were issued, a substantial increase on last year, partially reflecting the relaxation of pressure from international commitments.

Close contacts have been maintained with universities undertaking research in agriculture and allied subjects and with the research stations of the Agricultural Research Council and also those of the Ministry of Agriculture, Fisheries and Food. There were also many individual inquiries from farmers, research students and others.

Obervational Requirements and Practices

The Branch is responsible for the requirements, techniques, standards and accuracy of surface and upper-air observations on land and at sea. The Head of the Branch is the chairman of the committee charged with the task of reviewing the U.K. observational network and making recommendations for additions and improvements. The Branch is the essential link between the instrument development and supply branches and the users such as the forecasting, climatological and hydrological branches. It is responsible for the field testing of new and modified instruments in order to ensure that they are suitable for operational work and that their introduction would not lead to an unacceptable decrease in accuracy or a fall in standards. The Branch, together with other branches, has been engaged in preliminary work which may ultimately lead to a Weather Radar Network; the stage has now been reached when equipment is being gathered for a joint study, with the Royal Radar Establishment, Malvern, on the development of a system for digital transmission of radar data and for display in a form suitable for making quantitative estimates of areal rainfall. The study may be completed by the end of 1973. The Marine Division under the Marine Superintendent is part of the Branch.

Observational practices

Trials to assess the field performance of new and modified instrument systems against standard instruments continued at the experimental site at Beaufort Park near Bracknell, at the observatories and at operational stations. Observations at all synoptic hours were commenced at Beaufort Park in the autumn, and this enabled field trials to be made at night as well as by day and provided additional routine reports to the operational branches. Data on the performance of transmissometers at three outstations, on the new telemetered Mk 5 anemometer system and on a mast-top rain-gauge at Beaufort Park were analysed; the results in each case were promising. Recommendations on the instruments and observation programme for U.K. ships expected to participate in the GARP Atlantic Tropical Experiment (GATE) in the east Atlantic in 1974 were made to the U.K. GATE committee.

Observatories

The observatories at Kew and Lerwick and the meteorological section at Eskdalemuir have continued their work on trials of new instruments and techniques; the special facilities available at these stations enables them to go

into more detail than would be possible at most other stations. Important examples of this work are the comparison of evaporation tanks at Kew and Eskdalemuir and the evaluation of the performance of the dewcel, an instrument for measuring dew-point, at all three places. A preliminary analysis of the dewcel results confirms that the instrument is suitable and sufficiently accurate for operational use. At Kew the effects of different lengths of cotton sleeving on wet-bulb thermometers (both mercury-in-glass and electrical-resistance) are under investigation. In collaboration with the Operational Instrumentation Branch a prototype reference aspirated psychrometer was constructed at Kew to the specifications laid down by a working group of the WMO Commission for Instruments and Methods of Observation (CIMO). The purpose is to produce an instrument with accurately known psychrometric properties which could be used to make a comparison between the various national standard instruments used for measuring humidity.

Work is in hand on comparisons between temperatures recorded by standard aspirated psychrometers and observations made in the thermometer screens in use at the three stations. A report has been completed and will be published in the *Meteorological Magazine* on comparisons made at Kew between the psychrometer records and readings in the north-wall screen and the conventional large screen. The gravimetric rain-gauge, which was mentioned in the *Annual Report* for 1971, was completed and installed early in 1972. It gives consistent and reliable results and it appears to have ample sensitivity. Work on the comparison of this new gauge with standard rain-gauges has just started.

For a long time Kew has been the centre for meteorological radiation measurements in the U.K. and it is a WMO Regional Radiation Centre. In spite of this, it has been accepted that there will be distinct advantages in moving the Radiation Centre to Bracknell where major instrumental and computer facilities are available. It is expected that this move will take place in 1973; routine radiation operations will however continue at Kew.

Lerwick has continued to act as a WMO Regional Sampling Station for the measurement of background pollution. The examination of the Lerwick solar radiation records, in order to establish any long-term systematic changes in atmospheric turbidity, has continued and it is planned to extend this work to the records of other stations.

Thunderstorm location

The network of Cathode Ray Direction Finding (CRDF) stations continued to function throughout the year; the station at Malta was inoperative, however, between 8 March and 22 July. Direct teleprinter links between CRDF Beaufort Park and the CRDF units in the Mediterranean were installed during the year and are being used for the rapid passing of 'fixes'. These links complete Phase 1 of the plan to automate the complete system. Thunderstorm location data have been supplied on request to research units at home and overseas.

Surface observations

In the U.K., 78 surface observing stations report in international code every hour of the day (24 hours) throughout the year; a further 50 stations report every 3 hours. In addition 143 stations report at various times each day of the year. Of this total of 271 stations, 107 are manned by full-time professional staff and 164 by voluntary observers most of whom have attended a course in observing held at the Meteorological Office College. Because of a pay dispute the 42

auxiliary stations manned by coastguards stopped reporting early in October. The loss of these reports was a serious handicap to forecasting, especially for shipping and RAF operational training flights. Representations to this effect were made to the Department of Trade and Industry.

Reports in plain language are received from 23 town offices of the Automobile Association and the Royal Automobile Club, 21 Police or Fire Service stations and 49 road maintenance depots located along motorways.

Upper-air observations

The normal programme of upper-air observations was maintained at eight stations in the U.K., at four ocean weather stations, and at five stations overseas. Balloon performance was not quite so good as in 1971. The high-altitude balloons each cost about half as much as the type used in former years. This enabled nearly twice as many to be flown for the same cost, but the number reaching 10 mb was slightly less than formerly. The upper-air station in Malta was closed during March and April and the soundings were recommenced on 5 May. Radiosonde observations continued to be made from two merchant ships by Meteorological Office staff. Advice and assistance were given when required to other branches of the Office concerned with upper-air investigations and also to the International and Planning Branch which is responsible for the establishment of overseas upper-air stations in support of the World Weather Watch programme. One of these stations, located in the Anglo-French Condominium of the New Hebrides commenced operations in April. Assistance was given to the Operational Instrumentation Branch during a trial at Beaufort Park of the Finnish and Japanese temperature reference sondes.

Runway visual range calibration

Routine check calibrations of the human observer system used to assess runway visual range in foggy conditions have continued at most civil airports in the U.K. The work has increased and it now includes routine checking of the recently installed systems at 15 RAF stations in the U.K. and West Germany. Automatic runway visual range systems have been installed at London/Heathrow, London/Gatwick and Manchester airports but the human observer systems at these airports are being maintained in calibration for the time being.

Marine Division

The numerical strength of the U.K. voluntary observing fleet has remained almost static throughout the year. The six Port Meteorological Officers at the main ports, on whom most of the effort of building up the strength of the voluntary observing fleet rests, have found that frequently the number of new recruitments is equalled, and sometimes exceeded, by the number of withdrawals as a consequence of ships being sold, broken up or laid up for long periods. This pattern seems likely to continue for many years and it appears likely that eventually all but a few ships of the British Merchant Navy will be oil tankers, bulk carriers or container ships. To complete the change will take many years; in the meantime it is unlikely that a really significant increase in the strength of the voluntary observing fleet will be possible. At present it is barely possible to maintain it at its present level.

Some light in this somewhat gloomy picture is afforded by the fact that new ships, in the fitting-out stage, can be wired to carry distant-reading meteorological instruments. So far every shipping company approached has readily

agreed to this being done and seven ships have been fitted with distant-reading instruments. It is perhaps worth mentioning that the Sugar Line were the first in the field just as they were the first British company to carry a meteorologist aboard two of their ships for the purpose of making radiosonde observations as part of the World Weather Watch plan. The fitting of distant-reading instruments must be a continuing process, for naturally any ship's officer who has got used to recording weather observations from distant-reading instruments does not take kindly to a return to reading air temperatures from a Marine Thermometer Screen hung on the weather side of a wind-swept bridge or taking temperatures from a rubber bucket lowered over the side in severe weather conditions. There is the same feeling about taking pressure readings from a mercury barometer after serving in a ship equipped with a precision aneroid.

The standard of observing of voluntary observing ships has been, in general, well maintained throughout the year; where a deterioration has been noticed, and there have been very few cases, it has almost invariably been found in ships which are either now sailing with one deck officer fewer than previously, or in ships which are equipped with new electronic devices or new cargo loading and discharging apparatus. This is a psychological, rather than a meteorological, problem but it does show the necessity of continuing our practice of appointing Port Meteorological Officers who are themselves experienced mariners with considerable experience as voluntary weather observers, as well as being keen on the work and possessing the essential qualities of tact and patience.

The three hundred shipmasters, principal observing officers and radio officers who have sent in the most careful and painstaking log-books during the year were, as is customary, nominated for 'Excellent' awards, and barographs were presented to four shipmasters for their long and zealous meteorological work at sea.

Once again the Marine Division is indebted to many Port Meteorological Officers in Commonwealth and other countries for holding a small stock of instruments for the replacement of defective instruments on U.K. voluntary observing ships calling at their ports during protracted voyages away from the U.K., and for withdrawing instruments from such ships as may have been sold during their voyage. Such sales are not uncommon; sometimes they are not even notified in the shipping press until the sale has been completed, and, but for the timely intervention of Port Meteorological Officers overseas, our instruments might have been lost.

British Weather Ships completed a quarter of a century of continuous service in the North Atlantic during the year. The present four ships, ex 'Castle' class frigates built for the Royal Navy in 1944, have been in service as weather ships for about 13 years and though long past their prime and becoming increasingly expensive to operate continue to perform their arduous duty satisfactorily.

From the middle of June to the middle of July, for the benefit of competitors in the *Observer* Single-handed Transatlantic Yacht Race unable to pick up the special forecast from Bracknell, broadcast daily from Portishead, our weather ships on stations India and Juliett relayed the forecast when conditions were hazardous.

In July we were glad to welcome the French Weather Ship *France I* to Greenock on a two-day official visit. Although mainly a social occasion the opportunity was taken to exchange ideas on matters of common interest.

France I, a purpose-designed vessel, is much more spacious than our converted ships but carries the same complement of 52.

In September *Weather Adviser*, with the research vessels *Discovery* and *Researcher*, took part in a joint air–sea interaction experiment in the area of ocean weather station Juliett. The purpose of the experiment was:

(a) To examine the structure of the atmospheric boundary layer by means of repeated vertical soundings made simultaneously from three ships with radiosondes fitted with Loran/Omega Course and Track Equipment (LOCATE).

(b) To make spatial and temporal measurements of temperature and currents in the oceanic mixed layer with a view to including advective terms in heat-budget calculations for the mixed layer.

(c) To make surface measurements from three buoys to allow estimation of fluxes across the air–sea interface and of their horizontal variability. In particular, to measure horizontal pressure gradients to permit the calculation of the geostrophic wind.

(d) To test their ability to measure currents in the top 10–20 metres of the ocean in the presence of surface waves.

(e) To examine vertical gradients of currents and density at the bottom of the oceanic mixed layer and across the seasonal thermocline.

It is likely to be a long time yet before the results of this experiment are fully known but indications so far are that it was valuable.

The following additional observations were regularly made throughout the year by British Weather Ships: solar radiation and radiation balance, sea temperature and salinity down to the sea bed, magnetic variation and surface sea water sampling; also biological sampling for the Oceanographic Laboratory of the Institute for Marine Environmental Research using a Longhurst/Hardy plankton sampler to determine the vertical distribution of plankton in the upper 500 metres of the ocean at station India. For most of the year a scientist from the Institute was aboard a weather ship at station India in order to direct the sampling programme.

Communication and navigational facilities were provided for transatlantic aircraft by all the British Weather Ships. Search and rescue exercises were frequently carried out in which RAF Nimrod aircraft sometimes participated. Air/sea rescue equipment was kept in a constant state of readiness.

The radiosonde programme was continued aboard two ships of the Sugar Line each of which carried a meteorologist.

The number of marine inquiries was about the average for the last three years. The *Marine Observer* was published each quarter as usual.

Operational Instrumentation

The occupation of the new laboratories and workshops at Beaufort Park near Bracknell, towards the end of 1971, has already paid dividends in terms of a higher level of activity in the research and development field. The clearing, grading and seeding of the additional 30 acreas of land has transformed the original Experimental Site into a most useful trials ground which is now beginning to see the introduction of instruments both for operational use and for

evaluation. The new operational building and other associated facilities are also in full working order and have been the scene of important international trials during the year.

Operational instrumentation for routine use on land, at sea and in the upper air requires to be backed by a comprehensive service and is currently passing through a period of rapid technological change. To meet the growing demands of the forecasting, climatological and hydrometeorological branches for automatic and often remote data-acquisition systems, the Branch must gain an appreciation of their requirements, must adopt sensing methods with the necessary accuracy, and must plan the development, manufacture and introduction into service of the equipment with due regard to manpower and budgetary constraints.

Three topics deserve special mention this year: the introduction into service of the first of the new generation of automatic climatological systems using magnetic tape; the sea trials of our first telemetering meteorological buoy; and the evaluation in flight of the new Mk 3 radiosonde against reference radiosondes from two other countries.

It was noted in the 1971 *Report* that 30 magnetic-tape event recorders were undergoing field trials at 10 outstations. The particular application here was to record the total and time distribution of events from tipping-bucket rain-gauges, hitherto used only for synoptic purposes, and subsequently to translate the field tapes into a form suitable for computer processing for hydrometeorological purposes. Following the achievement of a 90 per cent data retrieval rate, authority was given for the equipment to be introduced into operational service and for further recorders to be procured. Responsibility for the recorders and for the translator has now passed to the user branch.

Work on modifying a small automatic recording buoy, previously used in air/sea interaction studies, was completed in the first half of the year as part of a joint programme with the Directorate of Meteorology and Oceanographic Services (Naval). The 2·5-m diameter toroidal buoy has been equipped to telemeter data at half-hourly intervals over a 150-MHz radio link to a shore station. The main purpose of the experiment is to use the buoy as a 'test bed' for the evaluation of a range of marine sensors which might prove suitable for use on ships, buoys and other platforms. For its first sea trials, the buoy was moored 10 km from the coast in Cardigan Bay for the three months June to August. During this period, observations of air and sea temperature, wind speed, humidity and pressure were received at Aberporth with a data recovery rate of about 90 per cent. The real-time monitoring of sensor performance has already given invaluable insight into areas needing further development. (See Plate I.)

One of the Working Groups set up by the WMO Commission for Instruments and Methods of Observation (CIMO) is concerned with arranging international comparisons of reference radiosondes, and with determining how the latter should be used to evaluate the performance of national operational sondes. Beaufort Park was readily accepted by WMO as an ideal site for completing the present phase of the work which began eight years ago. In addition to the standard-sized balloon shelter, a large rotatable balloon shelter had been commissioned. The new operational building, which was designed for radiosonde trials work, had also been recently equipped with the latest type of wind-finding radar. A second radar was available to complete the facilities.

The international comparisons which took place in September were between the temperature reference sondes of Japan and Finland. Teams from these countries flew a total of 16 twin flights, half by day and half by night. As a separate exercise, the U.K. team, comprising staff from several branches, flew Mk 3 radiosondes immediately before and after each twin flight. The arrangements for launching, radar tracking and radiosonde signal reception required effective management, communications and technical support of several kinds and the multi-national party was eventually able to launch the balloons at intervals of three minutes. Results had to be processed within about 24 hours, either on the IBM computer (Mk 3 sonde) or on a programmable desk computer (Japanese and Finnish sondes). It was a source of considerable satisfaction to find that the Mk 3 radiosonde agreed consistently with that of Japan. Figure 2 shows the most-probable estimate of the differences between the two systems, together with the associated standard deviations. Nowhere do the differences exceed 0·4 degC (at an altitude of 10 km), and for the most part they are less than 0·2 degC. It is believed that these data represent the limits of accuracy of present-day radiosonde technology. The daytime results show the same general level of difference, from which it is inferred that the corrections applied for the

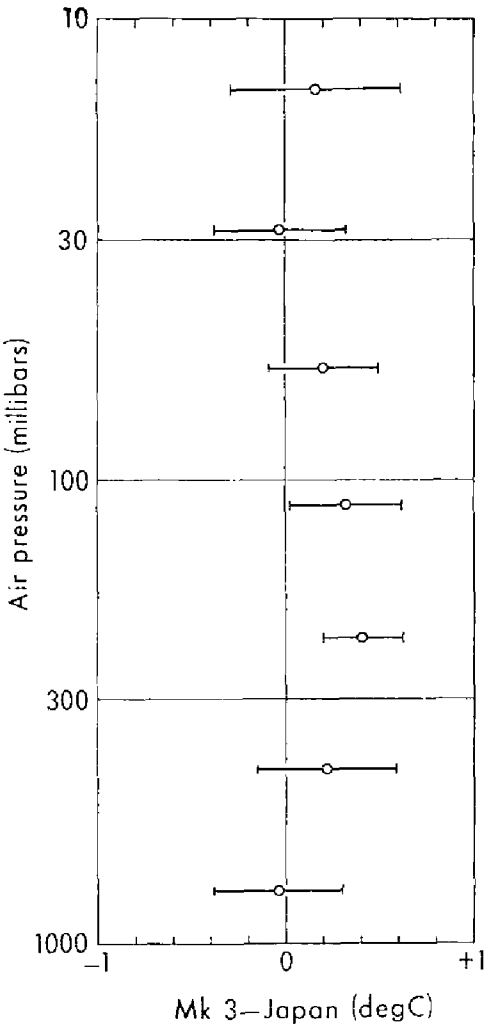


FIGURE 2—MOST-PROBABLE ESTIMATE OF THE DIFFERENCE BETWEEN TEMPERATURES MEASURED BY THE MK 3 RADIOSONDE AND BY THE TEMPERATURE REFERENCE SONDE OF JAPAN

The limits corresponding with plus and minus one standard deviation are indicated by vertical bars.

effect of solar radiation are approximately correct. This has been a region of much uncertainty with existing national sondes.

Co-operative projects: national and international

Shortly after the completion of the international trials of reference radiosondes, the CIMO Working Group on Radiosonde Instruments and Measurements met at Shinfield Park near Reading under the chairmanship of one of the officers of the Branch. The content of the report to be presented at the Sixth Session of CIMO in 1973 was discussed, and the results of the recent trials were studied.

As part of the work of another CIMO Working Group, which is concerned with the development of an interim reference psychrometer, a prototype instrument has been constructed and field and laboratory studies initiated to investigate its performance under a wide range of environmental conditions. Staff at Kew Observatory have continued to help with the work.

Discussions under the European Economic Community scheme for co-operation in scientific and technical projects continued throughout the period in the field of oceanographic/meteorological buoy networks, and on the development and standardization of meteorological instruments. On the latter topic, a two-year programme has now been approved in which special emphasis will be given to automatic weather stations, radiosonde and wind-finding systems and balloons. Support was also given to the series of informal Dutch/German/Belgian/U.K. talks on a Joint North Sea Information System.

As reported last year, the Department of Trade and Industry has arranged for the inter-departmental Committee on Marine Technology to sponsor the design and development of a national data buoy. The design phase started at the National Institute of Oceanography in January, and the Branch has been involved in all the meteorological aspects.

Automatic picture transmission (APT) stations were installed for the reception of satellite cloud pictures in Nigeria and Ghana under the Voluntary Assistance Programme of WMO. Training in operation and maintenance was also given to the local staff in these countries.

The Branch continues to be responsible for the technical management and operation of the Llandegla Research Station as part of the Office's contribution to the Dee Weather Radar Project. Towards the end of the year, continuous 24-hour manning was introduced for half of each month in an attempt to gain a more complete picture of rainfall and run-off. An automatic programming device has been developed to control the sequence of positions taken up by the aerial of the weather radar.

A new involvement has been the examination, with the Police Scientific Development Branch of the Home Office and the Transport and Road Research Laboratory of the Department of the Environment, of the possibilities for making automatic measurements of visibility as a means of reducing motorway accidents in thick fog.

Development, production and evaluation of new instruments and systems

Field trials of the Mk 5 anemometer system were successfully concluded, early in the year, and the first production version was manufactured in our own workshops. This will replace three separate Mk 4 systems, at present in service at London/Heathrow Airport where the large number of displays required will

in future be provided by the one system. The all-important telemetry link will be duplicated to avoid any risk of breakdown in the service.

A new system for telemetering data from several remote sensors has been developed during the year. Known as the Continuous Automatic Remote Display system (CARD), this provides a continuous display, over a single telephone line. The first operational system has been installed to telemeter data from the new observing station at Beaufort Park to the Central Forecasting Office some 4 miles away. It now seems likely that there will be other applications in the near future.

Manufacture of the data-handling equipment for the Mk 2 land automatic weather observing systems is well advanced; development of the sensor interfaces and special test equipment has also been completed, and construction of these is being carried out in our own workshops.

In addition to the magnetic-tape event recorders described earlier, steady progress is being maintained with the preparation of a comprehensive range of magnetic-tape data loggers for operational service. The two loggers being manufactured for evaluation as replacements of existing paper-tape loggers are about to be delivered. Development and construction of the prototype logger intended to record the essential statistics of a wind record have been completed and preliminary field trials begun. These automatic climatological systems incorporate a standard tape-deck and the field tapes will be translated by a minicomputer and replay deck for which financial approval has been obtained. Laborious and time-consuming manual analysis of charts will be largely eliminated by the new generation of equipment.

A steady flow of production contracts has followed the successful flight-proving trials of the Mk 3 radiosonde system which took place in 1971. There are, however, several more to be placed and the heavy burden of contractual work will extend well into next year. Tendering exercises for some components of the system have not been initially successful, and this has resulted in much revision of specifications and drawings. Proving of the ground receiving-equipment was completed, and the basic computational programs were adapted for use in real time by the station data processors.

In the field of sensor developments, the emphasis has been on the measurement of humidity, and the precision humidity generator has again been extensively used to evaluate sensor characteristics. A new electrical hygrometer, first referred to in last year's report, has now been investigated in the laboratory, at land stations and on the telemetering buoy. It appears to have a stable calibration, it uses little power, and the effects of marine and industrial contaminants can be removed by washing.

The small but systematic differences reported last year between humidity readings from mercury-in-glass and electrical-resistance thermometers, and subsequently confirmed by wind-tunnel experiments, revealed that different psychrometric constants should be applied in the two cases. A theory has now been developed which correctly indicates the effects observed in screens.

Three automatic sunshine transducers have been built to the latest pattern, and preliminary trials are proceeding. It is intended to use these with the Mk 2 weather observing systems as an indication of state of sky.

In the balloon field, the use of special high-altitude balloons on midnight ascents proved to be satisfactory in summer but disappointing in winter. This is reflected in the lower percentages reaching 10 mb shown in Table V. However,

there was a marked improvement towards the end of the year with the introduction of similar balloons obtained from an alternative manufacturer. A prototype steam/methanol hydrogen generator has been evaluated and found to be suitable for meteorological use where the demand is intermittent or where there are power supply problems.

Technical management

In the foregoing sections, the main emphasis has been concerned with the scientific responsibilities of the Branch, with the research and development projects being pursued, and with the introduction into service of the resulting instrumentation. The success of these activities depends in no small measure on the way in which the remaining sections in the Branch work closely together to deal with the more routine aspects of production, inspection, installation and servicing.

At the beginning of the year, these interrelated functions were brought together under a newly-created post of Technical Manager. The management services function was strengthened, particularly in the fields of planning and costing of projects.

Technical services and facilities

In addition to the 10-cm wind-finding radar mounted on the roof of the new operational building, trial facilities for aerological work have been further improved by the acquisition of a mobile 3-cm radar. A 'kytoon', or small kite balloon, has also been obtained for low-level experiments. Experience of launching radiosondes from the prototype rotatable balloon shelter is being obtained at times of strong winds.

The radiation work at Kew will be transferred to Beaufort Park, Bracknell, in 1973 as soon as the necessary works services have been carried out; the Regional Radiation Centre will be housed in the original Field Station building, while radiation instrument development and calibration will be integrated with corresponding work on other types of instruments in the Branch's new headquarters block at Beaufort Park. A new integrating sphere has already been designed and constructed for the calibration of pyranometers.

Work commenced towards the end of the year on moving the wind-tunnel from the Dines Wing to a new site near the radiosonde calibration plant at Eastern Road, Bracknell. The main workshop continues to be fully stretched in spite of small staff increases. The new, small mechanical workshop in the Dines Wing was completed early in the period, and has been a useful addition to the range of facilities available. It provides a quick-turn-round service for small jobs, which is specially relevant to the needs of the research branches which are housed on the same site.

The high level of activity in the Branch, and in the research branches, has given rise to a steady increase in demands for engineering drawing office services. This has only been met with some difficulty, and a large part of the work has had to be carried out by contract draughtsmen.

Technical liaison and equipment installation

Work associated with the processing of production contracts rapidly increased with the simultaneous onset of the contractual phases of two complex,

major projects—the Mk 3 radiosonde system and the Mk 2 automatic weather observing system—and the necessary degree of liaison between the many groups involved has required the introduction of Project Evaluation Review Technique (PERT) charts for monitoring progress. Other contracts during the year included those for the supply of magnetic-tape event recorders, magnetic-tape data loggers, cross-wind resolvers, new wind-finding radars and data print-out equipment for existing wind-finding radars.

Technical liaison with users and manufacturers, the handling of technical inquiries, and the preparation of the drawings, specifications and other documentation associated with the production, testing, installation, operation and servicing of equipment, continued to absorb considerable effort. The introduction into service of a wide range of new devices has necessitated a new approach to technical writing, and a start has been made to co-ordinate this activity more effectively within the Branch, and to arrange for closer control of outside contracts for operating and servicing manuals.

In addition to projects mentioned under previous sections, other equipment installed, relocated or recommissioned included four APT sets, 12 cloud-base recorders, the 10-cm wind-finding radar in Malta, two 3-cm wind-finding radars at South Uist and Beaufort Park, the weather radar in Cyprus and one transmissometer at London/Heathrow Airport.

The post-design services section has carried out substantial improvements to the experimental Mk 1 automatic weather observing system on the Lichfield IBA mast, and has provided additional technical support to the Dee Weather Radar Project at Llandegla Research Station.

Instrument testing, calibration and standards laboratory

Table XV shows the number of instruments or items of equipment which were tested or calibrated during the year. The drop in the number of general meteorological instruments is due to the fact that far fewer radiosonde parachutes were handled; in most years these contribute the greater part of the total. The general trend of work continues to move away from routine acceptance testing of large numbers of minor items. The emphasis is now on calibration and specialized testing of more complex systems, both in prototype and final production form, in order to ensure that as many potential faults as possible are detected before the equipment is tested under operational conditions. The revenue obtained from work carried out for outside authorities shows a marked improvement on recent years.

Work on calibrating Mk 2 radiosondes continues at a high level to build up the reserve stocks which will be needed when staff are diverted to handle the new apparatus for calibrating Mk 3 radiosondes. Some of the latter equipment is now being manufactured, and works services for housing the semi-automated plant will start shortly.

Comparisons of the Office's pressure standard with the national standard at the National Physical Laboratory have continued satisfactorily. It was decided to set up a corresponding standard for temperature, and a precision platinum resistance thermometer and bridge is being acquired for this purpose. Apparatus has also been constructed for the calibration of inspector's mercury-in-glass thermometers, thus providing for the first time a comprehensive service for calibrating all types of meteorological thermometers.

Servicing and technical training

The demands placed on the Regional Servicing Organization continue to grow. Its traditional role is to provide a comprehensive maintenance and inspection service for all operational meteorological equipment at home and overseas. Use of such equipment has been increasing for many years, and the diversity of types has also become wider because very few of the earlier types have yet reached the end of their economic life and the new systems are generally introduced to meet new requirements.

By way of illustration, the following new types of equipment have been introduced into service during the five years 1968–72: Mk 1 automatic weather observing systems, tipping-bucket rain-gauges and magnetic-tape event recorders, Mk 3 transmissometers, Mk 5 temperature bridges and electrical-resistance thermometers, telemetry attachments for cloud-base recorders, automatic range-change devices for anemometers, dewcels, 3-cm wind-finding radars and data print-out equipment for 10-cm wind-finding radars. In addition to new types of equipment, there has been a steady increase during the same period in the numbers of the following established types of equipment: 10-cm wind-finding radars, 3-cm and 10-cm weather radars, cloud-base recorders and automatic picture transmission sets. The latter group of equipments, in particular, make heavy demands on local servicing staff.

A recent influence has been the developing requirement of operational users to have equipment on remote sites. Obvious examples are automatic weather observing systems on TV masts, for synoptic purposes, and automatic recording systems for climatological purposes. Other requirements, which seem likely to stretch the organization geographically, are the instruments installed on merchant ships, research vessels, buoys and marine platforms. Technical support is also provided for meteorological telecommunication centres and facsimile networks, and was especially vital during the move of the main Meteorological Telecommunication Centre at Bracknell to the new Richardson Wing in June.

In the last two or three years, demands placed on the Branch as a whole have made it necessary for staff in the Regional Servicing Organization to assist with installation of minor items of equipment, field calibration checks of certain equipment and user evaluation trials at selected outstations. This development of closer links with headquarters activities will strengthen the feedback of technical information, based on field experience, to the designers and those responsible for supporting documentation.

Wide-ranging studies have been put in hand during the past year with a view to determining the most cost-effective methods of servicing; these include a re-examination of the maintenance services which are really necessary to meet various operational requirements, a study of the influence which improved design can have on servicing and the extent to which intervals between servicing visits can be increased without adverse effects on overall serviceability. To this end, the Branch has also commissioned an operational research analysis of the work of the Regional Servicing Organization.

Trainee technicians continue to attend a basic electronics course at RAF Sealand, followed by an intensive course at the technician training school at Beaufort Park where they gain familiarity with both theoretical and practical aspects of the current range of instrumentation; other technicians attend short courses on equipment new to them. Special arrangements are made for overseas students sponsored by the British Council and WMO.

Computing and Data Processing

The Data Processing Branch operates the main scientific computers, the punched-card installation and much of the other data-preparation equipment. It is responsible for the software requirements for computer operation and for the programs necessary within the IBM 360/195 computer for the extraction of synoptic data for day-to-day operational use for numerical forecasting, chart plotting and graphical display. It is also responsible for some of the programs necessary within the 360/195 computer for interfaces with the telecommunication systems.

Meteorological Computing Laboratory—IBM 360/195 *computer*

The main task throughout the year has been to bring the new 360/195 computer into full operational use. This has involved the development of operating systems for the 360/195 well adapted to the needs of the Meteorological Office, the continued development of programs for the recognition of synoptic data from the telecommunication paper tapes, the ensuing subjection of these synoptic data to quality control and the storage of the checked data in a synoptic data bank. The Branch has also developed programs to enable data to be retrieved from the synoptic data bank for a variety of purposes. Extensive training of staff to operate the 360/195 took place in the early months of the year and much work was also done in developing suitable procedures and the organization required to ensure the operation of the 360/195 computer to a regular timetable as required for operational purposes. Apart from some limited interruptions due to electrical power problems arising from the coal miners' strike and also the failure of some parts of the electrical switch gear, the 360/195 has been operated continuously throughout the year. Good progress was made with the many interlocking tasks needed to bring the computer into full operation. In the early months of the year routine tests of suites of programs for numerical forecasting were run to fixed schedules. By April the running of the 3-level numerical forecast suite and the supporting organizational procedures on the 360/195 had reached a sufficiently high standard of reliability to permit the 360/195 to replace the KDF9 on 1 May as the main operational computer for numerical forecasting. On 1 August numerical forecast routines based on a 10-level model for an octagonal area of much of the northern hemisphere were brought into operational use in place of the 3-level model. Throughout the year the work for many branches of the Office was progressively transferred from the KDF9 computer to the 360/195 computer. By the end of the year the number of jobs on the 360/195 for routine operational numerical forecasting exceeded 1500 per week and for other work 2500 per week.

The hardware configuration of the 360/195 had been reviewed in 1971 and had been planned so that the configuration would incorporate the most recent and up-to-date equipment. As most of these technically improved equipments were not available until 1972 the initial configuration during October 1971 included several units on temporary hire until the newer devices could be delivered. Consequently in the early months of 1972 there were several changes to the hardware. In the first two months two banks of twelve exchangeable magnetic disc drives were installed. Each bank of six drives has its own controller which is attached by a block multiplexer channel as a primary connection and it also has an associated software switch which provides connection through another block multiplexer channel. After installation and the completion of

satisfactory site trials the two banks of 16 older-style exchangeable magnetic disc drives on rental were withdrawn. In March and April six new-style magnetic-tape units with self-loading facilities were installed in place of the six older-style drives. Two of the faster wider line printers were incorporated in the system in the first half of the year and one of the two slower and narrower line printers was subsequently withdrawn. In September three cathode-ray tube (CRT) terminals and two associated matrix line printers of moderate speed were installed. One CRT and printer function as a standby console for the main computer and have replaced a teleprinter-type terminal which had been on temporary hire. The other two CRT terminals and their associated printer function as remote terminals. Two more CRT terminals are due for delivery in 1973. In addition the CALCOMP 1670 Computer Output on Microfilm (COM) equipment was installed and brought into use. Thus the year has been characterized by many changes to the hardware with consequent effects on the flow of work and the development of suitable operating routines. There has been remarkably little adverse effect on the use of the 360/195. This has come about through the planning, perseverence and ingenuity of the staff concerned and the willing co-operation and forbearance of many systems analysts and programmers from many other branches.

The installation of the several new items of equipment described in the preceding paragraphs of this section has necessitated consequential changes to the software programs which are resident in the 360/195 and are used to control it. In addition there were many other changes which needed to be incorporated to make the controlling software more suited to the needs of the Office and to the changing workload.

Throughout the year work has continued on the production of a bank of synoptic data for the last 60 hours 'on line' to the computer on a magnetic disc. The work has involved the development of operational programs for the reading of many paper tapes produced by the Meteorological Telecommunication Centre at Bracknell from synoptic data transmitted to and from H.Q. Bracknell. After some initial problems the reading of paper tapes into the 360/195 was brought into operational use by the end of April. There has been much effort devoted to writing additional programs to improve the checking of the synoptic data and, in some cases, to calculate more correct values. As these programs need to work reliably and regularly to fixed operational schedules day in and day out the work needs very thorough testing and checking on the computer before it can be introduced into regular day-to-day use. This involves virtually duplicate running of some complex suites of programs and the organization of the work and the timing of the tests are matters of considerable complexity to ensure that the new routines under development do not interfere with and thereby invalidate some of the data and results from the operational sets of programs. The work has progressed well and the routines produced acceptable numbers of observations of suitable quality on virtually all occasions for day-to-day use for numerical forecasting for operational purposes.

The same synoptic data bank has been used to obtain selections of data needed for the development of programs for displaying such data on cathode-ray tubes at H.Q. Bracknell so that forecasters may inspect selections of data. Routines have already been developed which show on CRT displays the distributions of selected weather elements on base maps of the British Isles and also over much of Europe. Sub-routines have been developed whereby the

geographical scale of displays can be varied so that distributions of weather elements over larger or smaller areas can be suitably displayed. In addition distributions of temperature and humidity in the vertical can be displayed in the form of tephigrams and many of the synoptic messages can be displayed either as coded messages or in suitable tabulations. Development of these techniques, which show considerable promise, continues in collaboration with other branches.

Work has continued on preparation for the introduction of automatic machines for the plotting of meteorological charts and the drawing of meteorological isopleths. The specifications and characteristics of suitable machines currently available on the commercial market were reviewed in detail and several configurations of assemblies of COM and electro-mechanical equipment were assessed for their suitability to perform the work required for operational needs within acceptable time-scales. Towards the end of the year it seemed that there would be substantial advantage in automating the plotting and line-drawing in two stages and a suitable configuration of hardware to implement the first stage has been decided. Throughout the year work has continued on the development of software to drive the automatic plotters and line-drawers. The plotted output has to meet international standards and be suitable for transmission by facsimile. The characteristics of the commercially available plotters and associated equipment also impose a number of limitations so that the task of producing output of acceptable quality is a demanding one. Good progress has been maintained in developing suitable software and overcoming many of the practical problems. Early in the year software was satisfactorily developed in collaboration with IBM for the operation of the two KDF9 magnetic tape units which had been especially interfaced by IBM to the 360/195. The software was brought to an operational state in a very short time and the use of these KDF9 tape units has been of inestimable value in transferring work between the KDF9 and 360/195 computers—particularly for the development of operational numerical forecasting routines on the 360/195 whilst maintaining the full suite of routines on the KDF9 computer. The KDF9 magnetic-tape units will continue to be of great value in enabling the many hundreds of KDF9 magnetic-tape reels containing valuable meteorological data and results to be mounted and processed on the 360/195 system.

The development of suitable software and routines for the use of remote terminals to the 360/195 has commenced. Good progress has been made and the teleprinter-type terminals are now in use for restricted hours each working day. The volume of work has increased and demand for additional hours of service is growing. Development of software and procedures for the alphanumeric cathode-ray-tube terminals is progressing.

The successful operation of the 360/195 computer depends on many complex ancillary electrical and air-conditioning equipments. During the year some problems have been encountered with electrical generators and their automatic controllers and also with air-conditioning equipment. In addition some of the switches have caused some trouble. Many individual concerns and organizations have been involved in the installation, commissioning and maintenance of these supporting technical services. Problems which have occurred have generally been solved satisfactorily through the goodwill and co-operation of the several parties involved. A suitable standby electrical generator was delivered to site but installation had not been completed by the end of the year.

Arrangements have been made for a limited number of computer users from outside the Meteorological Office to utilize some of the existing spare computing capacity. The amount of spare capacity after the needs of the Meteorological Office have been met is expected to diminish so that the number of users and the time-scale over which their needs can be met have had to be kept within suitable small limits.

The Branch continues to be responsible for the organization of training in programming for the 360/195 computer. There has been a relatively small demand throughout the year and this has been met in full and in the right time-scale.

Twelve months' experience in operating the 360/195 computer in performing the workload demanded by branches of the Meteorological Office has revealed some limitations and restrictions in the configuration. Consideration is being given to the sort of hardware enhancement which is likely to be required to enable the Meteorological Computing Laboratory to meet the expected workloads in the future.

COMET computing laboratory

The ICL KDF9 electronic computer (COMET), which was installed in 1965, continued as the main operational computer for numerical forecasting using the 3-level atmospheric model until the end of April when it was replaced in that role by the 360/195 computer. On 1 May the hours of operation were reduced from 24 to 14 hours daily and were adequate to cope with the remaining workload for COMET. However, the KDF9 was kept powered up continuously so as to provide a back-up computer at short notice if required for operational purposes. The workload for COMET decreased during the remainder of the year but rather more slowly than expected. On 1 October the hours of operation were further reduced to 10 hours daily and in 1973 a further reduction to a 5-day working week is planned. Serviceability and reliability of the KDF9 computer have been good throughout the year. By the end of the year a good library of 5 years of synoptic data for much of the northern hemisphere had been processed and accumulated on KDF9 magnetic tapes.

Punched-card installation

The installation is equipped with a range of punched-card machines, including automatic punches and verifiers, sorters, collators, tabulators, and tape-to-card converters. Since the unit was set up in 1920 a library of about 60 million standard 80-column punched-cards containing surface and upper-air data from land and marine stations and surface data from voluntary observing ships has been accumulated. The present punching rate of British data is about $1\frac{1}{2}$ million cards per year and about a further $\frac{3}{4}$ million cards of selected foreign data are obtained through international exchange.

During the year work continued on the re-equipment of the punched-card installation with a processor-controlled keyboard system for recording data on magnetic media.

SYSTEMS DEVELOPMENT

The Systems Development Branch was established at the beginning of 1971 and charged with keeping abreast of new developments in electronic systems and applying them to carrying out the functions of the Office more effectively.

Broadly, the main tasks are to set up a general-purpose meteorological data bank on the IBM 360/195, to study new computer-based applications (possibly involving the procurement of other computers), to deal with the international aspects of meteorological data processing and to provide a mathematical advisory service.

Meteorological data bank

The objective is to convert the maximum amount of the available data to machine-readable forms and to make them available to users with the minimum effort. The main sources are the 1000 or so reels of three-quarter-inch magnetic tape which form the data library of the ICL KDF9 computer (now superseded by the IBM 360/195), around 30 million cards from the Punched Card Installation archives, punched paper tape from the telecommunication system, forms and log-books collected by post and cassetted tapes automatically logged from field instruments. These all have to be converted to IBM-compatible half-inch magnetic tapes and discs and, collectively, will ultimately constitute a library of more than 100 000 million (decimal) characters of information.

This conversion entails writing numerous computer programs to deal with the multiplicity of data types (upper-air, marine, synoptic and climatological and meteorological elements—pressure, temperature, wind, rainfall, etc.) involved. These have to be checked, corrected, combined and arrayed in particular ways to suit the principal users. Much of this programming work was completed by the end of 1972 when the routine build-up of the bank was actively under way. One particular item to which priority was given was the conversion from cards of the large amount of historic marine data in our possession. This was partly in pursuance of an international (World Meteorological Organization) undertaking between the Dutch, West German, American and British meteorological services to process certain elements (viz. sea temperature, air temperature, wet-bulb temperature, wind speed and direction, barometric pressure and total cloud amount) for all the ships' observations from all the oceans of the world, from 1960 back to 1860, or earlier if possible. These historic data amounting to about 30 million punched cards, will finally become available on magnetic tape, and statistical summaries, by months and for each 10-degree latitude/longitude square of the globe, will be published by the American National Weather Service.

Much of the data bank build-up was geared to the production of particular publications, such as the *Daily Weather Report* and the *Monthly Weather Report*, which require almost immediate outputs in particular formats and on various media (paper tape, magnetic tape, printer, microfilm, etc.). This was facilitated by the writing of access routines, both for fixed- and variable-length records, for general use by programmers.

Automatic reading of autographic traces

As a result of preliminary experiments it was established that the programmable film reader (a computer-controlled flying-spot cathode-ray-tube scanner) built by and working in the Nuclear Physics Laboratory, Oxford University, would be capable of reading pen-and-ink traces of rainfall, provided they were converted to microfilm. Accordingly a 3-year programme to convert to 16-mm film and to process the backlog of some two million daily rainfall charts was embarked on towards the end of the year. A point-by-point representation of

these traces is recorded on magnetic tape at Oxford together with hourly rainfall values, and this information is later absorbed into the Meteorological Office data bank for more-detailed analyses.

Data-entry system

In recent years the hand-punching on cards and paper tape of climatological data from postal returns has merely been a preliminary to their conversion on the H.Q. computer to the more efficient magnetic tape, as the main storage and processing medium. During the year the decision was made to go over to a modern key-to-disc data-entry system, especially as the punching equipment was wearing out. Accordingly tenders were invited and an order was placed by the end of the year, for delivery in the spring of 1973.

The chosen system (a Redifon Seecheck) has 16 keyboards, each with a cathode-ray-tube screen display, on-line to a small disc-based computer. This provides for a certain amount of immediate editing (at keyboard level) of the data which are subsequently transferred to magnetic tape for further checking and for inclusion in the main bank.

A mini-computer configuration at Bracknell

During the autumn it was decided that the conversion to computer-compatible forms of the data received from field loggers on quarter-inch and half-inch tape cassettes, would best be met by procuring a mini-computer to which suitable replay tape decks could be attached. However since there would be spare capacity on this machine, at least for the first two or three years while the coverage of field loggers developed, it became apparent that with enhancements such a system could also be usefully employed in a research and development capacity. For example, experiments on the digitization of analogue signals from radar, or facsimile or satellites could be undertaken or simulation exercises could be made of the functions to be carried out at Meteorological Office outstations of the future, including plotting and display of data, data collection and transmission, and data retrieval from the central bank. In order to meet all these requirements, invitations to tender for a mini-computer with a wide variety of input/output devices (disc, tape, printer, plotter, visual display unit, etc.) were issued in November, with a view to installation of the selected system by the autumn of 1973.

Cataloguing of literature and data

A study was started of the present functions of the Library, particularly the methods employed in producing the *Monthly Bibliography* and other catalogues of meteorological publications. Steps were taken to preserve on magnetic tape all the information included in the former from the beginning of January 1972, which in the long run could form the basis of an information retrieval system.

Some consideration was also given to the problems of classifying and cataloguing data, partly in view of exchange requirements with other meteorological services but also in connection with access to the main data bank via remote terminals.

Meteorological Telecommunications

The dominant factor within the field of meteorological telecommunications throughout the year has been the further development of automation in message handling, coupled with tests and trials at international level in an

endeavour to implement the plans of the World Weather Watch (WWW). Much of the Global Telecommunication System (GTS) of the WWW is designed to be operated at high speeds under error-control procedures, with pictorial information such as weather maps being transmitted over the same circuits on a time-sharing basis, and with nodal centres called Regional Telecommunication Hubs (RTHs) acting as input, output and switching control points. The backbone of the GTS is a major telecommunication highway called the Main Trunk Circuit (MTC), and this is designed to link together the three World Centres of Washington, Moscow and Melbourne, with on-trunk RTHs interspersed between them. The Bracknell RTH has been connected to the main trunk and has the task of feeding in surface and upper-air observational data from such areas as the United Kingdom, the Irish Republic, Greenland, Iceland, The Netherlands and Ocean Weather Stations A, I, J, and K in the eastern part of the North Atlantic Ocean; reports from selected merchant ships are included too. It also has the task of passing in the store-and-forward mode data received from Asia, Africa and Europe to the Washington World Centre, and from that Centre to other European RTHs data received from the Far East, North America, South America and Australasia. A further task is to extract data, including pictorial information for U.K. usage, and to route it to designated dependent national centres.

Bracknell RTH automation

The basic mode of operation, engineering characteristics and operational procedures for automated RTHs of the GTS have been evolved and agreed within the World Meteorological Organization (WMO) during the past few years. Because the technology of computer-controlled message-handling systems is still to some extent in an evolutionary stage, and also because in an international network interoperability can be achieved only by agreement which often involves compromise and changes, implementation of the on-trunk RTHs has been a rather slow and laborious business.

At the beginning of January 1972 the automated message-handling system was finally accepted from the contractor, although some testing with the Washington and Paris centres had been carried out during the previous two or three months. The heart of the automated complex comprises two Marconi Myriad II computers working in dual mode; a number of peripherals (especially disc storage) are also duplicated in order to ensure a high level of integrity and reliability. During the months of tests and trials which continued throughout the year, it was discovered that only the Offenbach centre had followed the same design philosophy. Interruptions occurred in the programme of operational trials when the French and American Services introduced requirements into their systems to achieve compatibility. In March the main regional circuit between Bracknell and Offenbach was established, and within the first two days of testing it was established that the automated systems of the two centres were compatible. Although at this stage, around the end of the first quarter of the year, tests had shown that the point had been reached where the Bracknell automated system was generally compatible with each of the other three centres so far as exchanging data in alphanumeric format was concerned, it was clear that quite a lot more work and testing would have to be done before full operational status could be achieved. A major problem has proved to be that of solving the handling on an automated basis of the 'oil-and-water mix' of digital

data transmission and analogue facsimile transmission. Yet another problem which has adversely affected all four centres and slowed down progress towards operational status has been shortage of staff.

When the automated complex was installed in mid 1971 in the Telecommunication Centre located in the Napier Shaw Building at the Bracknell H.Q., it was known that a new building, the Richardson Wing, was being constructed and that around mid 1972 the Telecommunication Centre with its automated complex would have to be moved to the new wing. The move of the complex needed to be carried out with minimum interruption to the operational trials. A scheme was worked out by the Telecommunications Branch engineering staff which in essence reduced the system to single-mode operation while the actual move was in progress, and then restored it to dual-mode operation at the end of the move. The transfer was executed very smoothly by the Marconi Company under a special contract, and very little time was lost.

At WMO meetings held in Paris in February and in Washington in September general reviews of implementation dates were carried out and it was agreed that the four centres of Washington, Bracknell, Paris and Offenbach with their interconnecting main trunk circuit segments would accept 15 February 1973 as the revised implementation date. On that date the Bracknell RTH will become the 'gateway' centre between Europe and North America on the GTS main trunk. Trials of the automated data exchange with Washington were sufficiently successful by 1 November 1972 for this to be used as the primary source of supply of observational data from North America, and the Central Forecasting Office and the Computing Laboratory from that date received page copy and punched paper tape respectively from the telecommunication automated complex.

Planned further telecommunication automation

Work has continued on plans and arrangements for the next phase of telecommunication automation. As well as maintaining the services provided by the present system, this will provide facilities for additional international connections to European centres, and introduce some improvements in the selection and earlier supply of weather information to meteorological offices around the United Kingdom. In July the contractor for the next system advised the Office that he could not maintain the forecast delivery date of October 1973, and that January 1974 was his revised hand-over date. This announcement of yet another delay caused concern, and in order to reduce the chances of still further delay occurring, arrangements were made to send a meteorological systems-analyst and a programmer to the contractor for a period of several months to learn about the software design and the operation of the system, and to give meteorological advice on the spot as necessary.

During recent months feasibility studies have been carried out to ascertain the practicalities, time-scales and likely costs of enhancement of both the present automated complex and the one now in production. These studies have indicated that enhancement through the addition of a sub-system is a practical proposition and that it will be cost-effective if the right time-scale can be achieved. In order to progress further studies on enhancement of these two phases of telecommunication automation, and also to have concerted action in the planning of future phases coupled with the concept of a national meteorological data network, a planning team has been set up with specialized staff from the three branches

within the Deputy Directorate of Communications and Computing. In the meantime at the request of the Norwegian meteorological service, and until a medium-speed data transmission link can be established between Oslo and the Bracknell RTH, four Bracknell–Oslo 50-baud telegraph circuits have been established entirely at the expense of Norway. By means of these circuits Bracknell RTH will send to Oslo all the data required from Europe and North America.

Professional engineers

During the past year the policy of creating a team of professional engineers in the Telecommunications Branch has come to fruition. Although the science of meteorology is unfamiliar ground to most of the engineers, and they have much to learn about the peculiarities and special demands of meteorological communications, a number of engineering projects have been started, and in several cases completed. One important example is the scheme to introduce replacement facsimile recorders on a large scale, the design of the new recorders based on modern electronics techniques being influenced by our engineers. Another example in the facsimile area was the design of a large concentrator-switchboard, a piece of equipment which is unique. It was a vital link in facilitating the transfer of the Telecommunication Centre to the Richardson Wing with uninterrupted services. Engineering design effort has enabled certain hardware modifications to be made to the present automated system and a much-needed visual display unit is in the process of being added.

As the workload has been rather heavy, only a limited amount of time has been available to be devoted to studies on the digitization of pictorial information, compression coding and the speeding up of information transfer. During June and July, however, it was possible through a combined effort with the French meteorological service to carry out tests at Bracknell of a coded digitized facsimile system developed by the French.

Meteorological satellites

The main real-time source of satellite pictures during 1972 has remained ESSA 8, an American operational weather satellite. However, experimental 'APT-style' pictures have been received from the Russian satellite METEOR 10. Also, from time to time weather charts relayed by the American geostationary satellite ATS 3 have been received on an experimental basis at Bracknell. On 15 October 1972 the American satellite NOAA 2 was successfully placed in a Polar orbit. NOAA 2 carries only scanning-radiometer equipment for local read-out and requires special equipment to provide a complete picture at the ground station. Conventional automatic-picture-transmission (APT) recorders are not compatible with the new system, but all recorders of British origin installed in the U.K. and abroad have been modified and are able to produce a narrow strip of chart from NOAA 2 transmissions.

Discussions have been held with universities and industry in the U.K. on the possibility of building a machine to produce full-size pictures 8 inches (20 cm) wide, but so far a new design has not been forthcoming, mainly for economic reasons. The Meteorological Office has nevertheless ordered special recorders which will produce pictures of about 5 inches (13 cm) in width, these being more acceptable to the user than narrow strip recordings which would otherwise occur.

General telecommunication services

The general telecommunication services, both those provided at the Bracknell main centre and at outstation offices at home and abroad have continued mainly unchanged throughout the year. The U.K. radio broadcasts to meet agreed WMO and ICAO requirements for radio-teleprinter and radio-facsimile services have been maintained. Possible improvements to the radio-fasimile broadcasts from U.K. and Episkopi (Cyprus) are being investigated. Liaison visits have been made by telecommunication engineer staff to offices in the Near East, Middle East and West Germany. A new meteorological radio-teleprinter channel between Gan and Melbourne was opened at the end of February. Action has been taken to install facilities in the Bracknell Telecommunication Centre for operation over the Post Office Datel 200 Service.

International and Long-term Planning

While arrangements for managing international affairs in meteorology, both internationally and within the Office, have not changed significantly in the past year, the steady increase in activity has continued over a broad front. The planning and implementation of World Weather Watch (WWW), and the development of the related Global Atmospheric Research Programme (GARP), form the framework within which innumerable developments in meteorology are interrelated. Very many of these are dependent on international co-operation and are usually in some degree the concern of the World Meteorological Organization (WMO).

Major WMO meetings during the year included sessions of the Technical Commissions for Hydrology and Marine Meteorology, an extraordinary session of Regional Association VI (Europe) and the annual session of the Executive Committee. The WMO Technical Conference on the Means of Acquisition and Communication of Ocean Data, held immediately before the session of the Commission for Marine Meteorology (CMM), covered a very wide range of topics. Information on the conference was passed to many universities, institutions and other non-governmental bodies in the United Kingdom. A total of 12 papers from the U.K. including 5 from the Office were presented to the conference and formed a substantial proportion of the whole. The extra session of RA VI was kept short by extensive correspondence beforehand, an experiment which was found to be effective and economical of time in session.

The Executive Committee's main problem was the financial crisis caused largely by the devaluation of the United States dollar in 1971. Severe economies were imposed which it is hoped will not too seriously impede necessary work. Other important matters included: approval of the Tropical Cyclone Project, of concern to some U.K. dependencies; the modification of weather and climate, intentional or inadvertent; and the means of ensuring continued operation of the weather ships in the North Atlantic after the termination in 1975 of the present ICAO agreement.

Action to help other countries implement World Weather Watch increased in scale. Besides another cash contribution to WMO's Voluntary Assistance Programme (VAP), and more fellowships given through VAP for university-level meteorological education in the U.K., necessary equipment of various kinds was provided either through VAP or bilaterally. Telecommunication equipment for collecting or exchanging data was given to Mauritius, Guyana, the United

Arab Republic and Ethiopia, ground equipment for direct reception of satellite picture was installed in Ghana and Nigeria, and a wind-finding radar was given to Mauritius. A telecommunication engineer visited Nigeria together with a party from WMO and another engineer visited Iceland, both in order to study on the spot how best to help in improving their meteorological telecommunication systems. An offer was made to WMO to share in an extensive co-ordinated programme of aid in central and west Africa and northern South America to improve the upper-air observations and the telecommunications for disseminating the observations there. A large number of other requests for meteorological aid were studied and some new projects set in hand. Offers were made, and accepted, of a wind-finding radar to Zambia and telecommunication sets to Botswana. In all this work other branches of the Office were heavily involved, especially the Telecommunications and Instrumentation Branches. The best solution is not always that originally suggested in the request for aid.

Implementation of World Weather Watch in the territories for which the U.K. is responsible internationally went on at an accelerating pace. The upper-air station in the New Hebrides Condominium, jointly supported by the U.K. and France, began operation early in the year. Building began on Tarawa and Funafuti in the Gilbert and Ellice Islands for the similar stations there. On Funafuti both the new constructions and the existing station were almost destroyed by a typhoon in October, and two of the staff lost their lives. The New Zealand Meteorological Service, which runs both these stations, immediately set in hand plans for reconstruction. The next WWW upper-air station in the U.K. programme is that on Mahé, Seychelles. Two officers visited Mahé in February to find a suitable site and make other preparations. Plans are now being developed to establish the station on the new airport with the co-operation of the Seychelles Government. The possibility of establishing new surface observing stations in the area was also discussed. Another officer visited St Helena both to prospect for an upper-air station there and to inspect, for the first time, the surface observing station which has been operated there since the Second World War. Operation of the station on Diego Garcia, Indian Ocean, which has been carried on for some years by Mauritius with U.K. support, was taken over by the U.S. Navy in February.

The International Scientific Management Group of the GARP Atlantic Tropical Experiment was transferred by agreement with WMO from Geneva to Bracknell. The staff comprises an internationally employed director and deputy-director supported by other scientists seconded from participating countries, including the U.K. Dr N. E. Rider returned to the Office in mid year after serving as interim deputy-director since 1970.

Arrangements were made with WMO for the excellent facilities of the Meteorological Office College at Shinfield Park to be used to host sessions of two WMO working groups. Also by arrangement a comparative trial of upper-air instruments organized by WMO was held at Beaufort Park. Several other small international meetings were held in the headquarters building during the year.

With the completion and final occupation of the Richardson Wing early in the year that major planning exercise came to an end. A study of the current use of the Office's buildings in Bracknell was carried out jointly with the Department of the Environment as a basis for further planning to meet the Office's needs for accommodation.

There was much activity throughout the year on meteorological projects under the European COST scheme (co-operation in science and technology). By far the biggest of these was that for a European Centre for medium-term weather forecasting, which will carry out research aimed at the production by means of numerical techniques of forecasts for 4–10 days ahead. A detailed offer to accommodate the Centre in Bracknell and later at Shinfield Park was made, and in October a small European party visited the sites offered. Together with other Departments involved, the Office gave extensive consideration to the draft Convention for establishing the Centre and to draft regulations for governing its operation.

P. J. MEADE
Director of Services

SUMMARY OF THE WEATHER OF THE YEAR (1972)

Two features of the weather of 1972 deserve special mention. One was the contrast between the general mildness of the winter and early spring and the coolness of the summer and early autumn—the abnormal coolness of June was especially noteworthy. The second feature was the spells of dry or almost dry weather in a number of districts during the summer and autumn with abnormally low rainfall in Northern Ireland and Scotland in September.

January. The year began with a changeable month during which winds were often strong, especially in western areas. It was colder than average at first with snow or sleet (rain or drizzle and snow) at times, mostly in England. Morning fog, freezing in places, was reported in many areas in England on the 5th and 6th and fog patches persisted in parts of the east Midlands and East Anglia throughout the day on the 6th. By the 7th it had become milder and temperatures during the next 10 days or so remained generally above average. On the 9th a temperature of 14·5°C was recorded at Lake Vyrnwy (Montgomeryshire) —the highest there in January since continuous records began in 1948. The first 11 days were almost without sunshine in eastern areas of England and Scotland and the dull spell continued in north Scotland until the 19th. On the 17th and 18th mean wind speeds of 40–50 knots in parts of Scotland preceded a cold spell of 4 days with snow in northern England and south and east Scotland. Frost persisted throughout the 18th in parts of east and north-east England. Continuous overnight rain on the 18th/19th in north-west England and south-west Scotland led to local flooding and 81·5 mm of rain were recorded at Coniston (Lancashire) in the 24 hours ending at 09 GMT on the 19th. Milder weather returned on the 22nd but on the 26th a deep depression crossed northern England and heralded a return to cold weather. On the evening of the 26th gusts of 60–70 knots occurred in South Wales and the West Country with gusts in excess of 50 knots in places as far apart as Argyllshire and the Channel Islands. On the next morning wind speeds reached storm force (i.e. a mean speed of 48–55 knots) along parts of the Yorkshire coast. The last 3 days were very cold everywhere and snow showers or more prolonged outbreaks of snow occurred

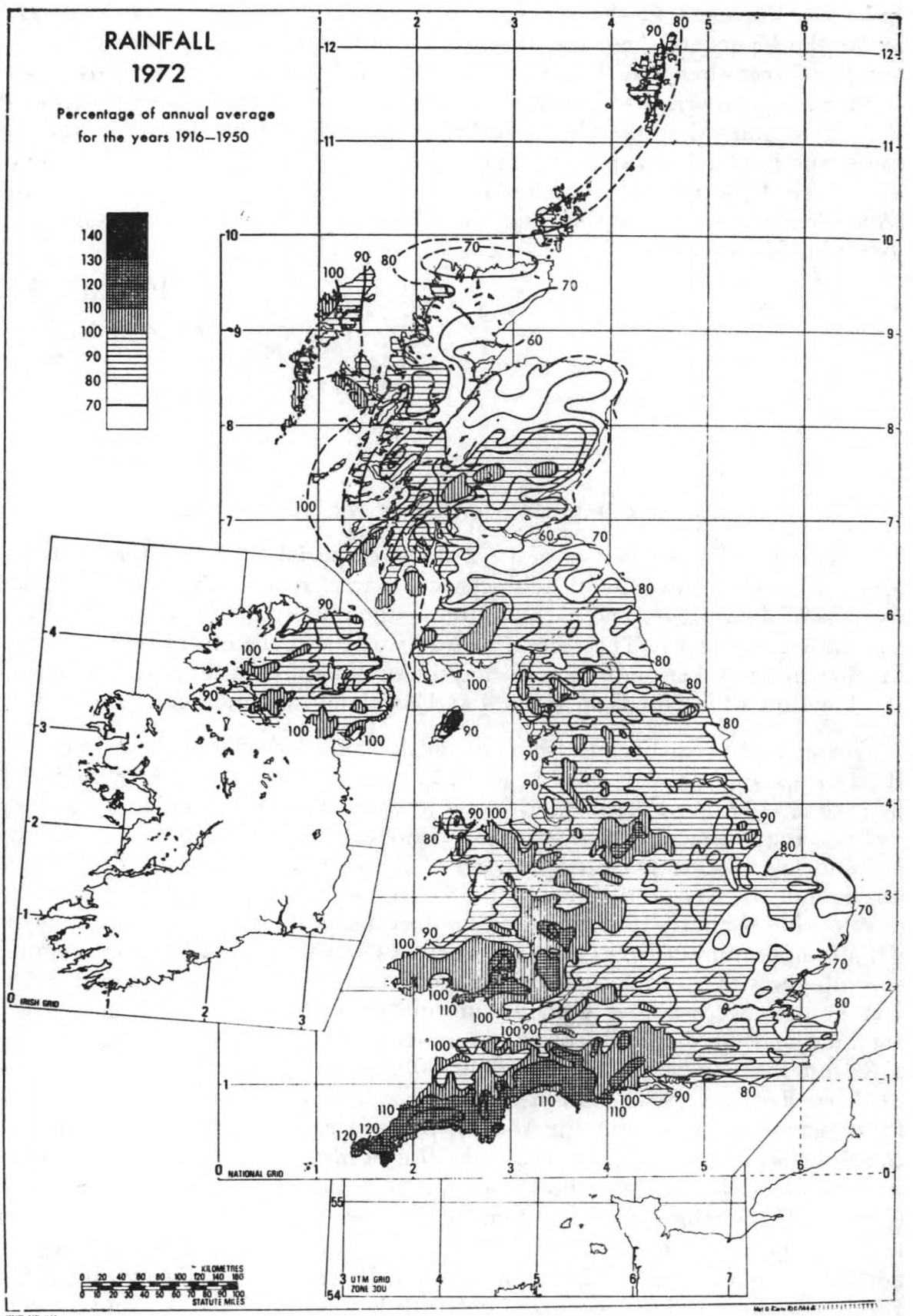
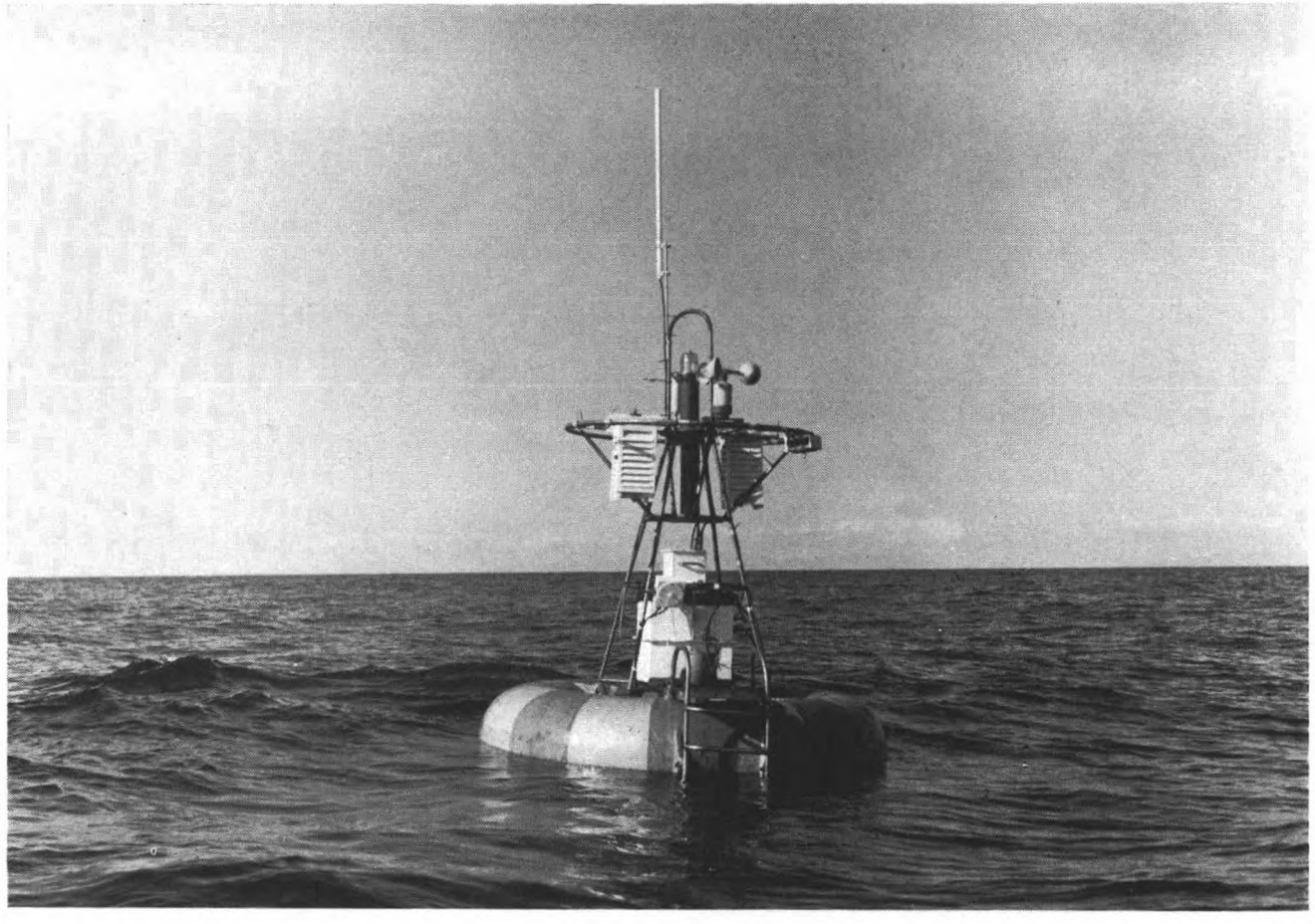


FIGURE 3—RAINFALL 1972



OFFSHORE BUOY OBSERVING EQUIPMENT—OBOE I

The photograph shows the Office's first telemetering buoy on station some 10 km off the Cardigan coast (see page 33).

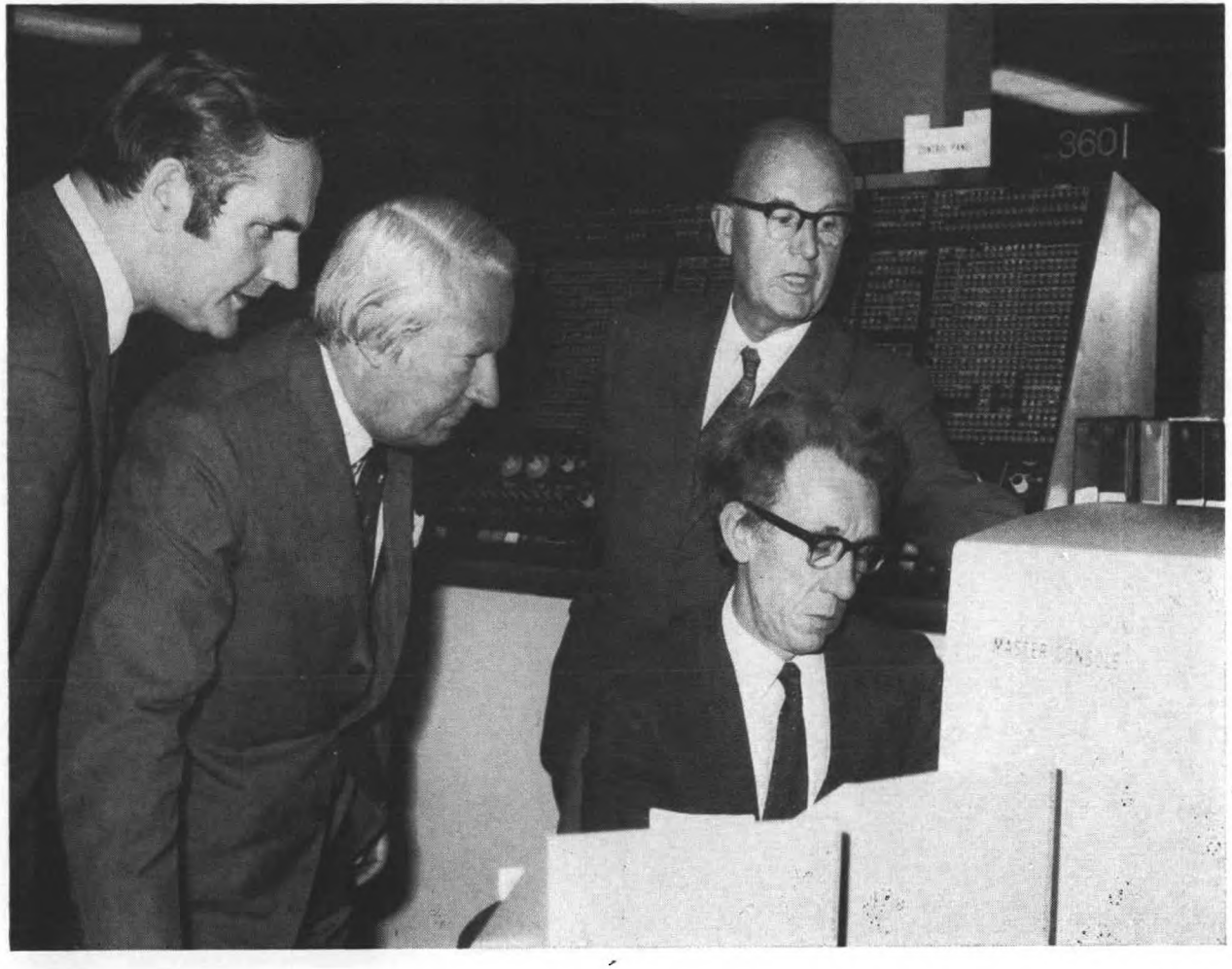
PLATE I

THE PRIME MINISTER VISITS THE BRACKNELL TELECOMMUNICATION CENTRE

The Director-General and Assistant Director (Telecommunications) illustrate reception of weather charts by facsimile technology from Moscow and Tokyo
(see page iii).

THE DIRECTOR-GENERAL DESCRIBES TO THE PRIME MINISTER THE NEW TELECOMMUNICATION FACILITIES WHICH PROVIDE MUCH GREATER SPEED AND FLEXIBILITY THAN WERE FORMERLY AVAILABLE

PLATE III



THE PRIME MINISTER AND THE DIRECTOR-GENERAL AT THE MASTER CONSOLE USED TO CONTROL THE IBM 360/195 COMPUTER

The seated operator, who controls the system by means of a keyboard, is guided by information displayed on a cathode-ray tube in front of him. The Assistant Director (Data Processing) is explaining the significance of the display and the effect of the controller's actions.

VIEW OF THE EXCHANGEABLE MAGNETIC-DISC DRIVES ON THE 360/195

One bank of six drives is in the foreground and an operator is changing one of the disc packs. The second bank is in the background behind the operator. Each disc pack provides 100 megabytes of on-line storage and the two banks provide 1200 megabytes (see page 2).

PLATE VI

VIEW OF THE SOUTH-WEST CORNER OF THE 360/195 COMPUTER ROOM

In the left background are the six 9-track magnetic-tape units. To the left of these units there is a cathode-ray-tube screen which displays information from the computer to assist the operator who controls the mounting of the magnetic tapes. In the centre are two paper-tape readers. The printer in the left foreground provides a record of work done on the computer (see page 2).

VIEW OF THE NORTH-EAST CORNER OF THE COMPUTER ROOM

On the left are the three line printers and the kneeling operator is attending to the output from one of the fast wide line printers. The operator on the right is attending to one of the card readers. The receipt and dispatch office is through the hatch in the background (see page 3).

THE FACSIMILE ROOM OF THE BRACKNELL REGIONAL TELECOMMUNICATION HUB IN THE NEW RICHARDSON WING OF THE METEOROLOGICAL OFFICE HEADQUARTERS

The photograph shows a part of the room. The staff member on the left is operating the central facsimile switchboard and concentrator; the other two members are attending to the loading of weather maps on to the drums of facsimile transmitters (see page 48).

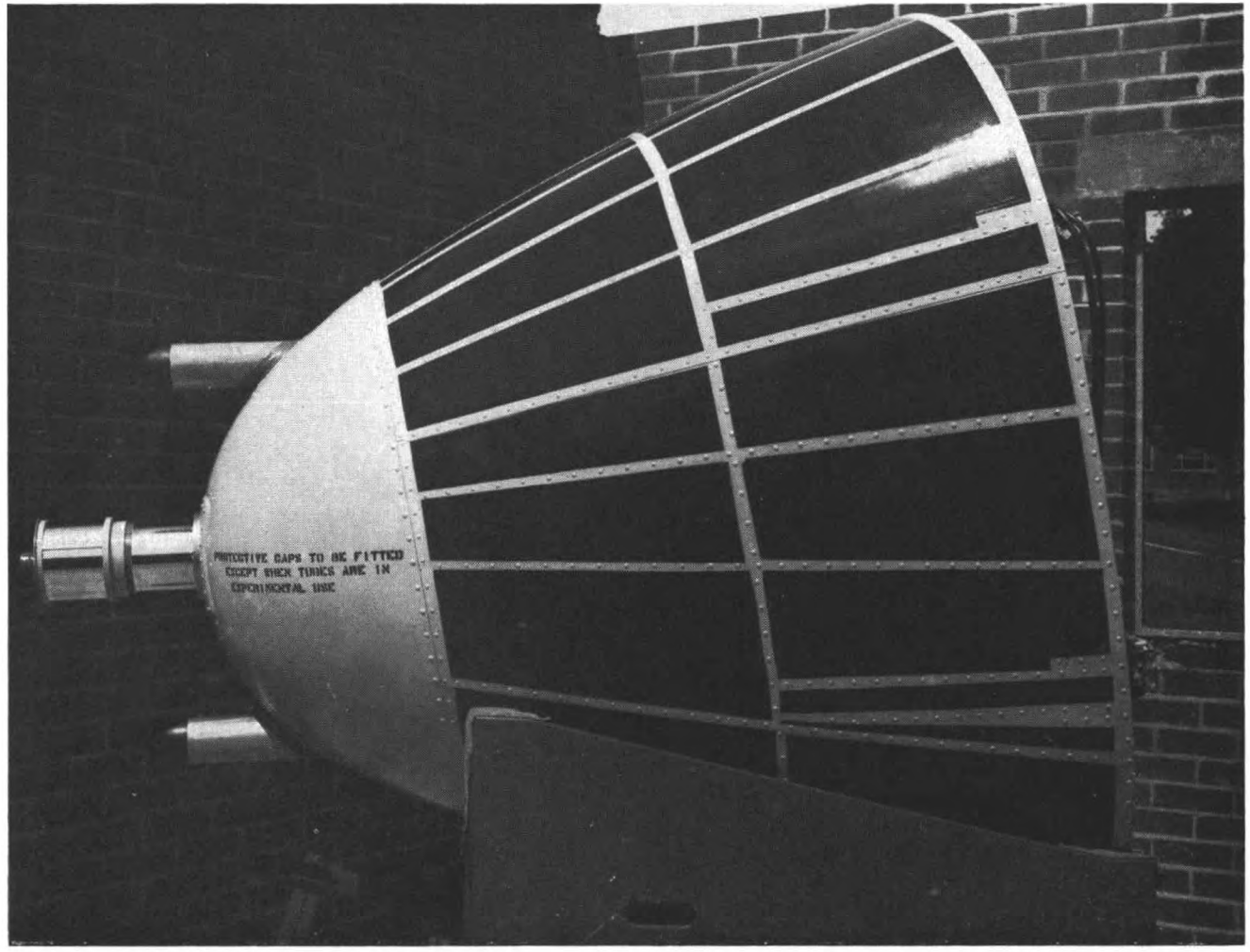
PLATE VIII

CENTRAL FORECASTING OFFICE AT METEOROLOGIAL OFFICE HEADQUARTERS, BRACKNELL, SHOWING SENIOR FORECASTER AND SUPPORTING STAFF AT WORK

See page 8.

CENTRAL FORECASTING OFFICE SHOWING CHART-PLOTTING AREA, WARNINGS BOARD AND CATHODE-RAY-TUBE GRAPHICS DISPLAY UNIT IN FOREGROUND

See page 8.

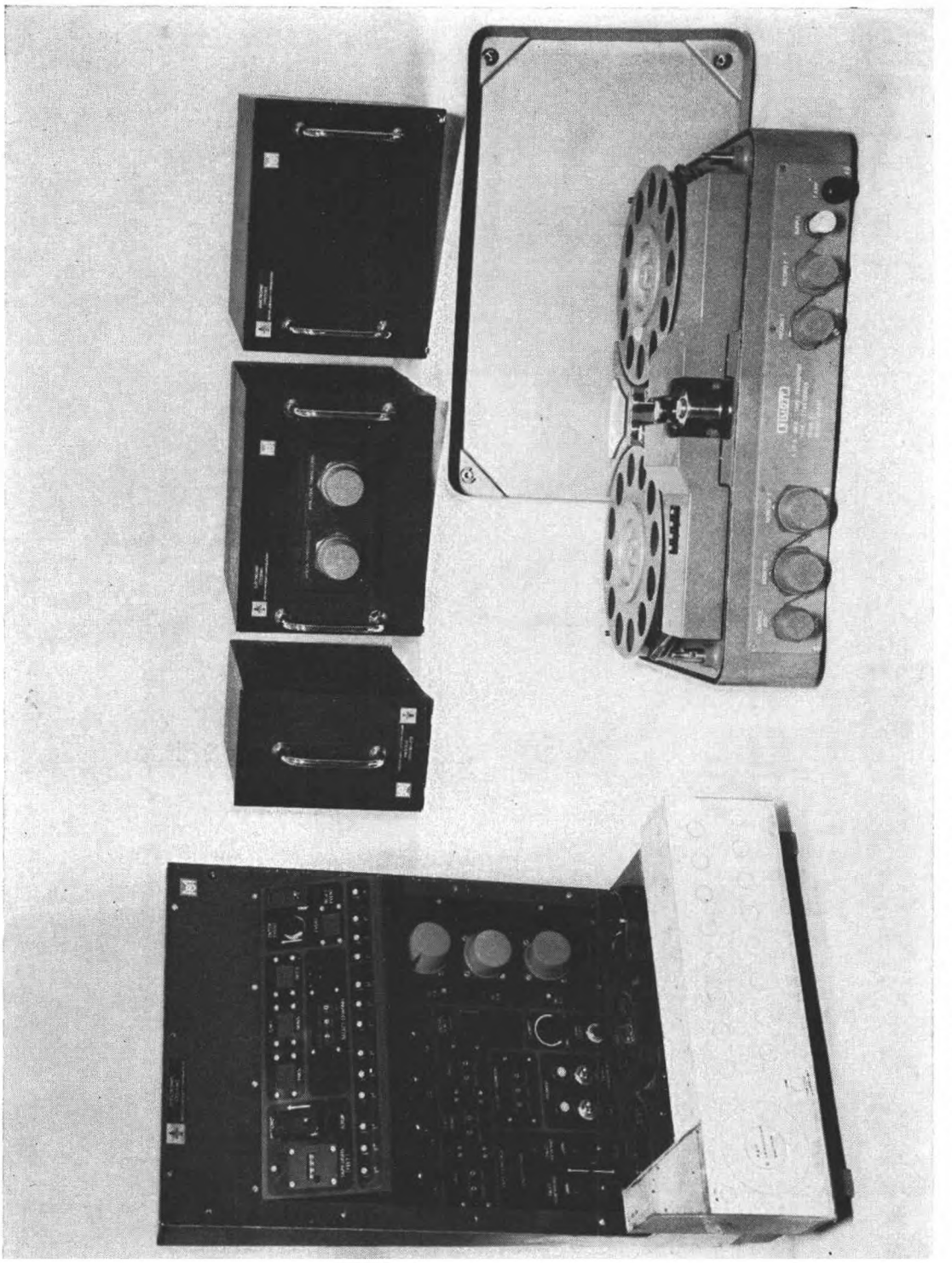


VARSITY NOSE CONE SHOWING FIELD MILL AND CONDUCTIVITY PROBES

See page iv.

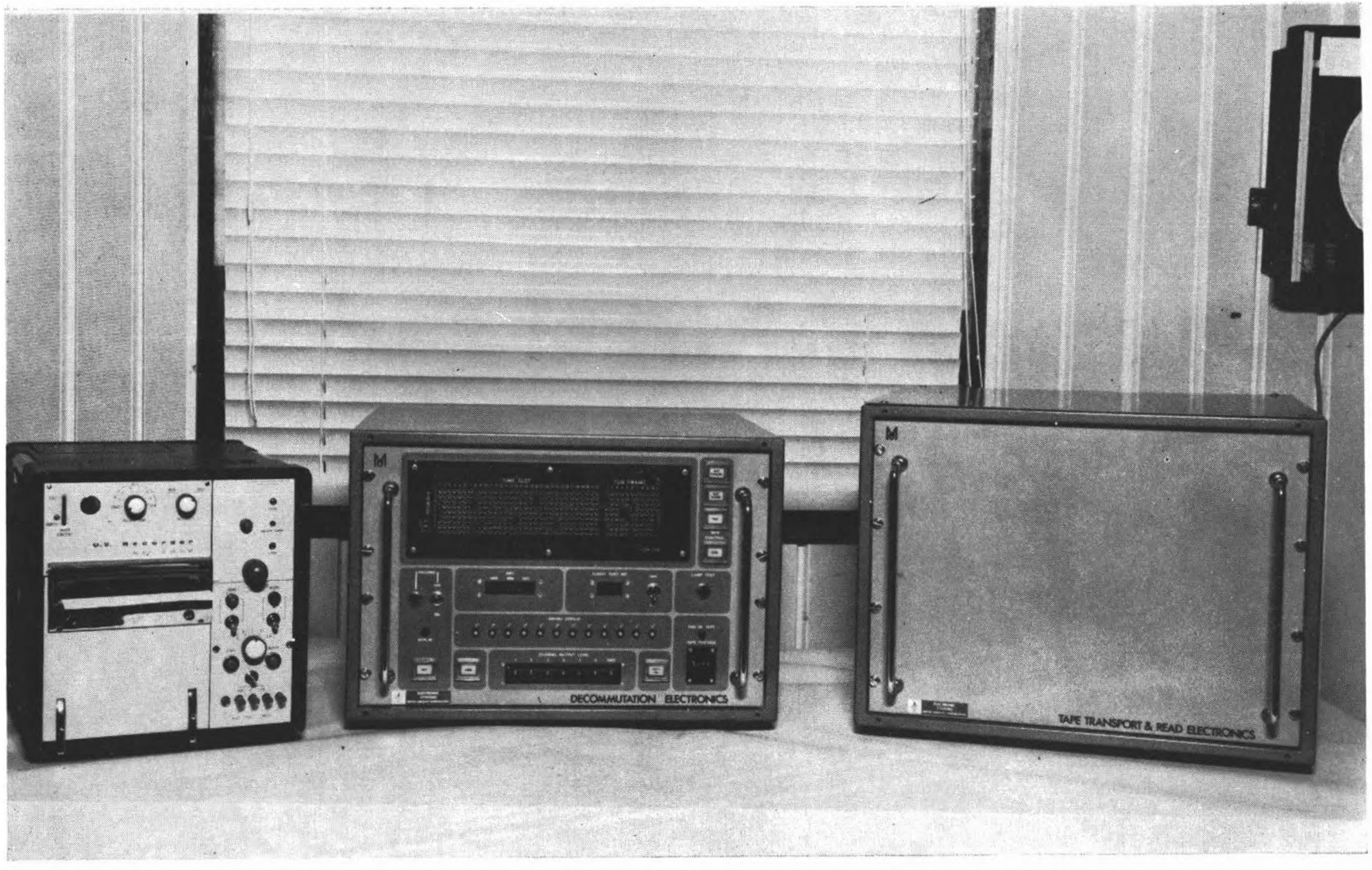
PLATE IX

PLATE X



THE METEOROLOGICAL RESEARCH FLIGHT AIRBORNE DATA-RECORDING SYSTEM

See page 81.

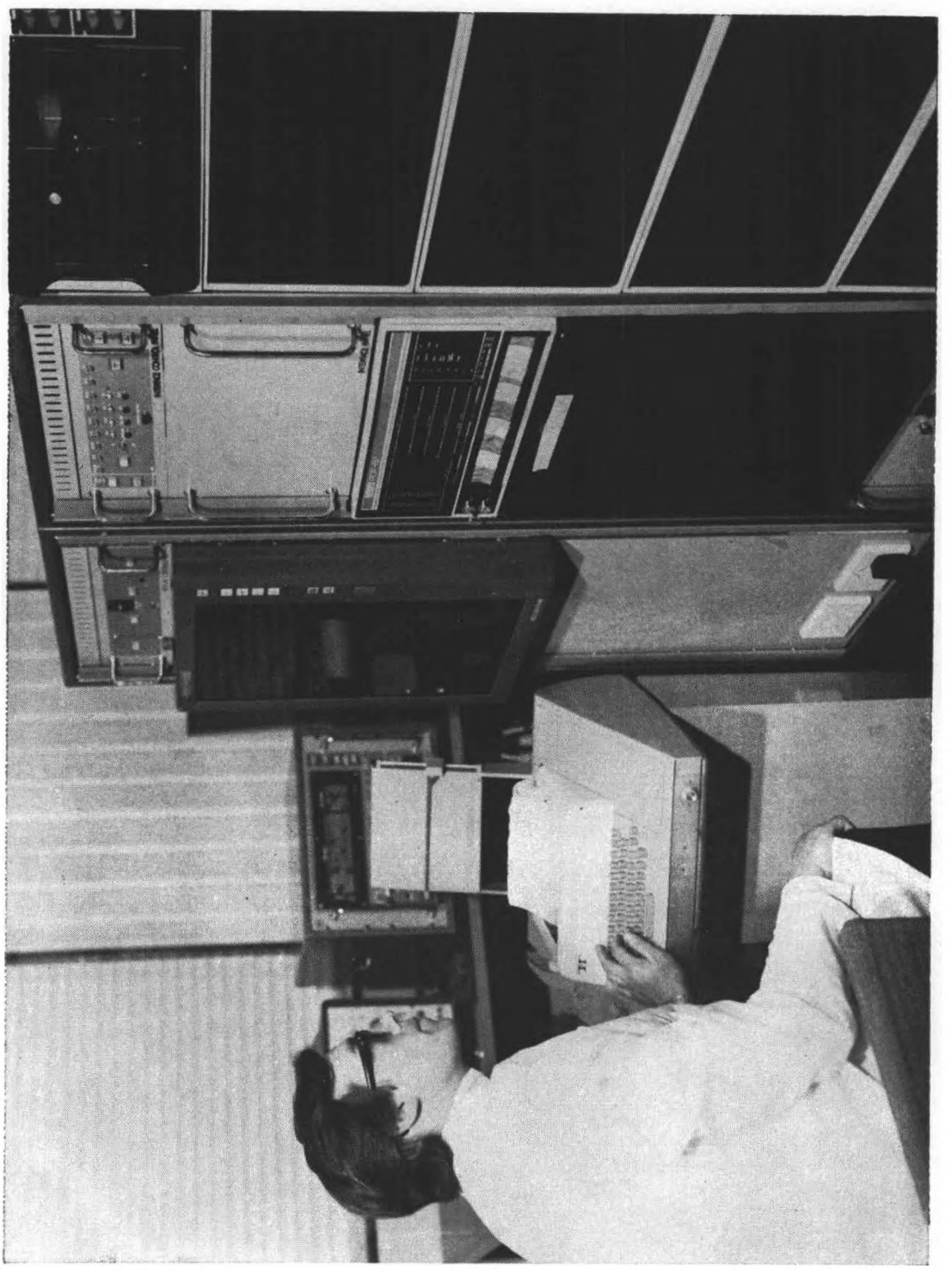


THE METEOROLOGICAL RESEARCH FLIGHT GROUND REPLAY EQUIPMENT

See page 81.

PLATE XI

PLATE XII



THE METEOROLOGICAL RESEARCH FLIGHT TRANSCRIPTION AND DATA-PROCESSING SYSTEM

See page 81.

in England and Wales, especially on high ground in northern England. Monthly mean temperature in most areas was near or slightly above average but most places had a dull month.

February. The cold weather with which January had ended continued on the 1st in most districts; on the morning of the 1st the temperature at Corbridge (Northumberland) fell to −18·3°C, and Leuchars (Fife) with −13·2°C had its coldest February night since records commenced in 1922. However, milder weather, preceded by sleet and snow, spread from south-west England during the 1st and 2nd and it became generally changeable. Although the snow did not lie for any length of time away from hilly areas, snow depths reached 20–30 cm in the more mountainous regions in the north. The first 4 days were stormy in Wales and the West Country, and gusts reached or exceeded 50 knots on the 2nd in localities as far apart as east Scotland and the Channel Islands. On the 2nd/3rd rough seas breached sea defences near Portland (Dorset), telephone lines and power cables were brought down near Seaton (Devon), and swollen rivers led to local flooding in a number of places. The changeable weather continued for most of the first half or so of the month with belts of rain, often followed by thundery showers, frequently crossing all areas, and strong winds often accompanied the rain. The 15th and 16th were very windy nearly everywhere and on the 15th heavy rain occurred in Wales and western England; in the 24 hours from 09 GMT rainfall totals of 93·2 mm and 90·4 mm were recorded at Treherbert and Llyn Fawr respectively (both in Glamorgan). During the third week snow or sleet occurred at times, mainly on high ground in the north and west but over the month as a whole snow was less frequent than usual. By comparison with the first part of the month the last 13 days were relatively dry but they were also virtually sunless in parts of eastern England where there were persistently easterly winds. Heavy 24-hour rainfalls of 80–85 mm occurred locally in the Mourne Mountains in Co. Down on the 27th. Although, in general, rainfall was close to average there were marked departures from average in many areas; Glamis Castle (Angus) had its wettest February since 1925 but in other places less than half the average amount was recorded. It was a dull month almost everywhere and Arbroath (Angus) had its dullest February since 1923.

March. Dull weather continued at first in eastern areas of England and Wales during a stormy first week by the end of which some places in southern England had recorded more than their monthly average rainfall. During this week deep depressions brought strong winds to all districts and minor structural damage occurred in parts of south-west England. Heavy rain and showers occurred in many areas and swollen rivers led to local flooding. In the 24 hours beginning at 09 GMT on the 2nd 53·2 mm of rain fell at Foffany Reservoir (Co. Down). A very deep depression near Northern Ireland overnight on the 3rd/4th gave wind speeds of 40–50 knots in north Scotland and a gust of 75 knots occurred at Benbecula (Inverness-shire)—the highest March gust recorded there since autographic records began in 1957. On the 4th heavy snow fell in the Scottish Highlands and over northern England, Wales and the West Country. Roads were blocked in the Cairngorms, 5–10 cm of snow settled in the Pennines and Welsh mountains and the moors in south-west England were snow covered. On the same day a 24-hour rainfall (including melted snow) of 58·7 mm occurred at Troed-y-foel (Carmarthenshire). On the 6th a deep depression moved east into

Ireland and then south across Cornwall giving gusts of 60–70 knots over Northern Ireland and one of 79 knots at Gwennap Head (Cornwall) while a 24-hour rainfall of 53·5 mm was recorded at Misterton (Somerset). The weather became relatively dry after the first week and only small amounts of rain occurred from the 9th to 24th despite isolated thunderstorms in some areas. Although east winds with snow showers kept eastern and southern England cold on the 11th (the day-time temperature in some parts of the West Country barely exceeded 0°C) it became gradually warmer, especially from the 14th to 25th. During this period, after cold nights and morning fog, it was often very warm by day away from the North Sea coast where sea fog was persistent for much of the time. On the 21st Hastings (Sussex) with 19·0°C had its warmest March day since continuous records began in 1947. Strong winds in north Scotland on the 21st and 22nd foreshadowed a gradual return to cold, windy weather with wintry showers during the last week or so. On the 27th/28th blizzards occurred in the Scottish mountains and roads were blocked by snow in the north Pennines. During the last 3 days parts of Wales had over 100 mm of rain, for example Blaenau Ffestiniog (Merionethshire) had 142·0 mm of which 73·0 mm fell on the 31st. Most of Scotland had below-average rainfall and Geanies House (Ross and Cromarty) had its driest March since 1929. Elsewhere rainfall was generally above average and Northern Ireland as a whole had its wettest March since 1947.

April. Most of the first half of the month was very changeable with strong winds. Belts of rain frequently crossed all districts, often followed by showers and occasional thunderstorms. Heaviest rain occurred in western areas where local flooding was often reported and by the end of this wet spell more than twice the monthly average rainfall had been recorded in parts of west Scotland. Here and also in north Scotland the first few days were particularly wet and windy. Heavy 24-hour rainfalls from 09 GMT included 78·2 mm at Blaran (Argyll-shire) on the 1st and 75·3 mm at Isle of Rhum (Inverness-shire) on the 3rd. Also on the 3rd gusts of 50–60 knots occurred in Scotland and over high ground in northern England. On the 6th and 7th it was very windy in England and Wales with, on the 7th, gusts of 50–60 knots in north-west England and a gust of 71 knots at Gwennap Head. Heavy rain fell on the 7th and 8th in Northern Ireland, southern Scotland and northern England with 70·7 mm of rain recorded at Lagafater Lodge (Ayrshire) in the 24 hours commencing at 09 GMT on the 8th. Strong winds occurred in many areas from the 9th to 11th; there were gales locally on coasts and strong gusts occurred at many stations including St Marys (Isles of Scilly) where 66 knots were recorded on the 11th. From the 14th to 27th showers, mostly in the north and east, produced only small amounts of rain while many places in Wales and western England remained completely dry during this period. North-easterly winds kept eastern districts cold for much of this period, notably from the 23rd to 25th when it was very cold in some areas. However, during this same period there were some sunny days in western areas of the United Kingdom. Heavy rain returned to all districts on the 28th and 29th with showers on the 30th. Overnight on the 28th/29th rain was heavy in Wales and western areas of England and Scotland. Among many heavy rainfalls recorded in these regions in the 24 hours beginning at 09 GMT on the 28th was 88·5 mm at Honister (Cumberland). It was generally duller than average, largely because of a paucity of sunshine during the first half of the month. Mean

temperature was near average and both the occurrence and amount of snow were very small, falls being usually confined to high ground. Rainfall in many districts was near average but in Scotland it was much wetter than average in the west where Eallabus (Argyllshire) had its highest April rainfall since records began in 1866; over Scotland as a whole it was the wettest April since 1947.

May. The weather was generally changeable with winds frequently in the north and west and this led to a cool month, especially in western and southern districts. Although on the 2nd the temperature reached 22·0°C at Brighton (Sussex), and generally in north Scotland and eastern districts of Great Britain there were periods with temperature above average, temperature in many areas during the month was often below average. The monthly mean temperature of 10·5°C recorded at Sandown (Isle of Wight) made it the coolest May there since 1941. Rain was a frequent occurrence and stations in some areas recorded rainfall on almost every day but amounts were often small, especially in the east. Much of the rain during the month fell in the form of showers, and thunderstorms occurred locally on many days. On the 6th, morning fog patches were reported in the east Midlands and East Anglia and hill fog occurred widely for a time. In addition, sea fog persisted throughout much of the day on the coasts of east Scotland and north-east and south-west England. Snow or sleet fell in the Scottish Highlands on the 7th and slight air frost occurred in parts of southern England during the following night. Overnight on the 10th/11th air frost occurred in parts of Scotland while ground frost was recorded more widely. During the succeeding day heavy rain fell in Northern Ireland, Wales and western England. After a spell of quiet weather for a few days around mid month, with night frost in many areas, changeable weather returned. From the 23rd to 29th deep and mobile depressions brought stormy weather to most districts; there were periods of heavy rain accompanied by strong winds, notably on the 25th and 26th in the west and north. A gust of 63 knots was recorded at Kilkeel (Co. Down) on the evening of the 25th and a little later the mean wind speed at the hill-station of Great Dun Fell (Westmorland) reached 60 knots with a gust of 80 knots. In the 24 hours from 09 GMT on the 25th heavy 'daily' rainfalls included 118·7 mm at Cononish (Perthshire) while on the 26th a 'daily' rainfall of 69·0 mm occurred at Lake Vyrnwy. Sunshine over the month was below average in most districts and, although deficits were generally small some areas were very dull. For example it was the dullest May at Fort William (Inverness-shire) and at Inverness since records began in 1891 and 1911 respectively. Rainfall was above average in most areas but parts of east Scotland were very dry.

June. Generally changeable and dull weather continued and, with temperature almost continuously below average, particularly by day, this resulted in an abnormally cool month. Overall it was probably the coolest June this century over Northern Ireland and the coolest since 1916 over England and Wales, while large areas in Scotland away from the north had their coolest June since 1928. Moreover, locally it was the coolest June for a much longer period, for example in the Falmouth area of Cornwall since at least 1869 and in the Manchester and Ross-on-Wye (Herefordshire) areas since at least 1886. Long-established stations which had their coolest June on record included Bournemouth (Hampshire) and Rhyl (Flintshire) since 1905, Teignmouth (Devon) since 1910 and Helensburgh (Dunbartonshire) since 1915. The coolness is

further indicated by the fact that over large regions of the United Kingdom the temperature did not reach 21°C—a very unusual occurrence in June. The tone of the month was set by slight air frost in parts of east Scotland early on the 1st and again overnight on the 2nd/3rd, while snow or sleet fell in the Highlands. Rain or showers were again a frequent occurrence and the heavy rainfalls in parts of the west and north were generally associated with troughs of low pressure; Truro (Cornwall) and Eallabus had their wettest June since 1912 and 1919 respectively. Except in parts of north-east England the month was less thundery than usual. The first week was windy with local gales over northern and western coasts, and heavy rain led to 'daily' rainfalls of 68·0 mm at Honister on the 2nd and 52·6 mm at Ogmore Vale (Glamorgan) on the 6th. Slight frost occurred in upland areas in Wales on the 11th/12th but heavy overnight rain in south-west England on the 13th/14th foreshadowed a brief respite from the cool weather in many areas for a few days around mid month. Morning fog patches formed during the period 12th to 16th, mainly in the Midlands and eastern England but heavy rain and strong winds in western Scotland and Northern Ireland on the 17th spread overnight to many other western areas. Gusts reached 40–50 knots in many parts of the north and west of the United Kingdom and in the 24 hours from 09 GMT on the 17th a prodigious 185·0 mm of rain were recorded at Honister. Strong gusts occurred again in many areas during the next 5 days. Further heavy rain in north and west England on the 25th/26th included a 'daily' rainfall on the 26th of 75·2 mm at Blaenau Ffestiniog. Except in Scotland it was generally a dull month, notably along the south coast of Devon where in places it was the dullest June since 1890.

July. The cool weather continued everywhere for a further 10 days or so and, despite some very warm days during the third week away from areas near the North Sea, monthly mean temperature was again below average in most districts although in many cases deficits were very small. The changeable weather of the previous months continued in the south until the 8th and in the north until about the 12th; there were some heavy rainfalls, mainly in the north and west, and on the 3rd and 4th frontal rain caused local flooding in Wales and north-west England. In the 24 hours from 09 GMT on the 3rd 104·8 mm of rain were recorded at Blaenau Ffestiniog and in a similar period on the 4th 110·0 mm of rain occurred at Honister, while over the 48 hours Beddgelert (Caernarvonshire) had a total rainfall of 128·9 mm. After the 8th it became more settled. From the 13th to 18th very little rain fell anywhere and it was very warm by day away from the North Sea coast where coastal fog patches were prevalent. Following temperatures of around 27°C in southern England on the 28th a violent thunderstorm occurred around midnight near Exeter (Devon) and caused lightning damage to buildings and disruption to telephones and electric power supplies. Rainfall was intense just to the north and east of the city where a number of rainfalls classified as 'very rare' were recorded in a small area; these included 89·1 mm in 132 minutes at Exeter Airport and 78·3 mm in about 2 hours at Rockbeare Manor. On the same night the Romney Marsh area of Kent had a severe thunderstorm during which lightning struck and killed a number of cattle and badly damaged the roof of the 12th-century church in Dymchurch. On the 20th the temperature at Perth reached 29·4°C, and Edinburgh/Turnhouse Airport with 28·4°C had its warmest July day since records began in 1948, while about the same date a number of locations

elsewhere in Scotland, and also in Northern Ireland and northern England had their highest July temperature since 1955. Outbreaks of thunder continued until the 24th, except in north Scotland. During thunderstorms in the north Midlands on the 23rd large quantities of hailstones fell in the vicinity of Nottingham (some 27 mm in diameter at Watnall) and a 'very rare' rainfall of 44·3 mm in 20 minutes occurred at Farley (Staffordshire). After another period of mainly dry weather from the 25th rain fell in most places on the 30th and thunderstorms recurred on the 31st in North Wales, the Midlands and East Anglia with some heavy rainfalls locally. Despite the thunderstorms, most districts were much drier than average. It was the driest July over Scotland as a whole since 1955 and at Arbroath (Angus) probably since 1898. Elsewhere, Aberdeen and Usk (Monmouthshire) respectively had their lowest July rainfall since 1913 and 1924 (when records began). Over most of central and southern Scotland it was the sunniest July since 1955.

August. The month began with very changeable weather but after the first week it became gradually more settled and mainly dry. No measurable rainfall occurred after the 8th in a few places in central and eastern England or after the 10th in some other areas of the United Kingdom except in Scotland where, notably in the west and north, rain continued at times until the 23rd. Rainfall over large regions was less than half the monthly average while locally it was less than a quarter of average; the Lowestoft (Suffolk) area had its driest August since at least 1862. Thunderstorms or outbreaks of thundery rain occurred in many districts on the 1st and continued in southern England on the 2nd. Early on the 1st at Costessey, near Norwich (Norfolk), a 'very rare' rainfall was recorded when 137·7 mm of rain fell in about 3¾ hours. Parts of Norwich were flooded and on the same day local flooding was reported in widely separated areas from North Wales to south-east England and a lightning strike resulted in the death of a boy in Chingford (Essex). From the 6th to 10th depressions over or near to the west of the British Isles brought strong winds and some heavy rain to many areas, and on the 6th and 7th sleet showers fell in the Cairngorms. Heavy rainfalls recorded during this period included 57·0 mm at Glenoglehead (Perthshire) in the 24 hours from 09 GMT on the 7th. On the 8th winds reached or approached gale force in many districts and gusts of 40–50 knots occurred in most areas. From about the 10th cool nights and short-lived morning fog patches were a common feature of the weather in many areas. Ground frost was often reported in the higher parts of Scotland, northern England and Wales and it occurrred even in the southernmost counties of England on a few nights around the 11th and 18th. Rain in north and west Scotland on the 16th and overnight on the 22nd/23rd led to a number of heavy rainfalls. These included the following in Inverness-shire, in a 24-hour period commencing at 09 GMT: 74·5 mm at Broadford on the Isle of Skye on the 16th, and 66·8 mm at Lag Garbh on the 22nd. The last week was dry almost everywhere and the month ended cool with air frost at Lagganlia (Inverness-shire) on the morning of the 29th when the temperature there fell to −0·6°C. Nearly everywhere monthly mean temperature was below average but sunshine amounts were above average except for a few areas in Northern Ireland and western Scotland which had their dullest August since 1942.

September. Rainfall was unusually low in many areas and abnormally so in the north of the United Kingdom where some places had only 1–2 mm of rain

during the whole month. Scotland had its driest September since 1894 while in Northern Ireland it was the driest September since comparable records began at the beginning of this century. Less than a quarter of average rainfall occurred over most of Northern Ireland and over much of Scotland south of the Great Glen, as well as in the Lake District and the Isle of Man. Rainfalls amounting to less than 10 per cent of the average were common in Northern Ireland and east and south Scotland where some stations with continuous records dating back to the 19th century had their lowest September rainfall on record. These stations include the following where the record began in the year stated: Loch Leven sluices (1842), Lothrie reservoir (1881), Carriston reservoir (1886), all in Fife, and Ballymena (1877) in Co. Antrim. Despite a warm start temperatures during the month were below average everywhere for most of the time; in many areas it was the coolest September since 1952 while Shawbury (Shropshire) had its coolest September since records began in 1946. The dry weather of late August continued everywhere during the first week and the temperature rose to 25·0°C at Mickleham (Surrey) on the 1st and to 24·8°C at Finnart (Dunbartonshire) on the 3rd. However, it soon became cool and a changeable spell from the 6th to 13th, during which snow or sleet fell at times in the Scottish Highlands, commenced with overnight rain on the 6th/7th in Scotland and Northern Ireland. On the 8th and 9th heavy rain in England and Wales associated with a vigorous depression ended a period of some 30 days without measurable rainfall in some areas. Rainfall was very heavy in South Wales and the Midlands; 71·6 mm of rain fell at Llyn Fawr in the 24 hours from 09 GMT on the 8th. Southerly gales affected the English Channel coast while gusts of around 40 knots occurred in a number of places early on the 9th. Mainly dry weather returned on the 14th and continued for the remainder of the month although eastern areas continued to have showers or a little rain at times until the 20th. Overnight on the 18th/19th heavy thundery rain affected parts of south-east England and East Anglia and 65·4 mm of rain were recorded at Southwold (Suffolk) in the 24 hours beginning at 09 GMT on the 18th. During the latter half of the month morning fog was a recurrent feature of the weather in England and southern Scotland. In general the month was sunnier than average in the west and duller than average in the east of the United Kingdom; Helensburgh in west Scotland had its highest September sunshine total since 1911 whereas Hull in eastern England had its lowest since 1941.

October. Rainfall in most districts was again very low and nowhere did it exceed the monthly average. Substantial areas in the eastern half of England and Scotland, together with parts of north-west England and Wales, had less than a quarter, and in some places not even a tenth, of average rainfall. At least two places, one near Witham (Essex) and one near Sudbury (Suffolk) recorded no measurable rainfall whatsoever. The Ipswich area of Suffolk almost certainly had its driest October since records began in 1872; it was the lowest October rainfall (3·6 mm) in the Ipswich Museum record which began in 1897. Farther north, over Scotland as a whole it was the driest October since 1951, but since 1924 locally in the east. Except in south-west England on the 1st and in the north and west of the United Kingdom from the 8th to 12th, only small amounts of rain fell during the first three weeks. It was not until the 21st that measurable rainfall occurred in some parts of the extreme east of England and Scotland. The first three weeks were also characterized by warm days after cold foggy

nights. From the 4th to 8th especially fog occurred widely night and morning in England, Wales and southern Scotland, and it was occasionally slow to disperse. On the 6th the temperature rose to 23·4°C at Grantown-on-Spey (Morayshire). During a changeable second week in the north and west of the United Kingdom heavy 24-hour rainfalls from 09 GMT included 55·0 mm at Glen Croe (Argyllshire) on the 8th and 57·5 mm at Princetown (Devon) on the 9th Snow or sleet showers occurred in the Scottish Highlands around the 20th but thereafter the weather generally was warm, windy and changeable although rainfall amounts continued to be small in eastern districts. During the 21st and 22nd heavy rain or showers in the North-west Highlands resulted in a rainfall of 63·9 mm at Kinloch, Reay Forest (Sutherland) in the 24 hours from 09 GMT on the 22nd. During the remainder of the month local gales were a common occurrence in the north and west. Gusts of 40–50 knots occurred on the 23rd as far south as Yorkshire. Similar gusts occurred there again on the 29th and 30th and also in Wales and western England as far south as Cornwall. Overnight on the 29th/30th gusts of 76 knots were recorded at Duirinish (Ross and Cromarty), Tiree (Argyllshire) and Great Dun Fell. Sunshine in Scotland was mostly above average and Prestwick (Ayrshire) had its sunniest October since 1932. Parts of north-west England were also sunnier than average but parts of south-west England and the Midlands were dull.

November. A return to generally changeable weather during the second week ended mounting concern over water shortage brought about by the relatively dry summer and autumn. Although rainfall in many eastern areas was again below average, deficits were mostly small while some parts of north and west Scotland and north-west England had nearly twice the average amount. The first week was generally warm and on the 6th unusually so in east Scotland where Gordon Castle (Morayshire) and Craibstone (Aberdeenshire) had their warmest November day since records began in 1879 and 1925 respectively. On the same day a temperature of 19·1°C at Gartly (Aberdeenshire) was the highest November temperature recorded anywhere in Scotland since 1946. From the 9th to 13th stormy weather occurred widely and it became colder. During this period strong winds and heavy rain caused minor damage and local flooding. Gusts of 50–60 knots occurred in many areas and on the 9th a gust of 82 knots was recorded at Great Dun Fell. On the same day a 24-hour rainfall from 09 GMT of 172·0 mm was recorded at Honister, in the Lake District, and the 12th and 13th were wet in most areas with drifting snow in the Pennines and Scottish Highlands. On the 14th fog patches persisted all day in the east Midlands. The 14th and 15th were very cold in Scotland and frost occurred widely at night. Rain in southern England on the 17th turned to snow over the higher ground where snow settled briefly, notably on Dartmoor. More heavy rain fell in western districts on the 18th and 19th with snow in the north Pennines where snowdrifts blocked some roads on the 19th. In southern England there was a short respite from the cold weather for a few days around the 21st and the last 4 or 5 days of the month were generally milder than average. However, they were also windy and wet at times. On the 29th another very heavy 24-hour rainfall occurred at Honister where 158·0 mm of rain were recorded. Monthly mean temperature was generally a little below average but it was sunnier than average in many areas and Cleethorpes (Lincolnshire) had its sunniest November since 1925.

December. Changeable weather continued during the first two weeks. Indeed, this period was often stormy with gales, and heavy rain which was occasionally accompanied by thunder. The heaviest rain fell in Wales and western England and the weather was at its stormiest on the 1st, 4th and 5th, and from the 11th to 13th. On the 1st a gust of 80 knots was recorded at Machrihanish (Argyllshire) and on the next day over 50 mm of rain fell in many parts of south-west England and caused flooding in places. On the 5th gusts in excess of 100 knots occurred over high ground in Scotland and gusts of some 80 knots and 40–50 knots were recorded respectively at lower levels in the north and south of the United Kingdom. At the same time heavy rain fell again, notably in western districts, while snow occurred in the Southern Uplands. By the end of the first week many places in the West Country had recorded more than the December average rainfall. Further heavy rain on the 11th and 12th gave some very large 24-hour rainfalls in the Lake District. On the 13th gusts again exceeded 100 knots over the Scottish Highlands and 82 knots were recorded at Lossiemouth (Morayshire). The latter half of the month was much less changeable and it became mild at times. However, overnight fog became a recurrent feature in the south and east, especially from the 16th to 22nd; on a few occasions fog persisted all day in eastern England. On the 27th and 28th there was a brief return to changeable weather, notably in Wales and south-west England where there was heavy rain, and a gust of 55 knots was recorded at St Mawgan (Cornwall) on the 27th. The year ended with a sharp contrast between the weather in the north and south of the United Kingdom. While the last few days over Scotland and Northern Ireland were changeable and mild, in southern and eastern England it was cold and foggy. Monthly mean temperature generally was above average. Parts of north-east England and east Scotland were much drier than average but much of south-west England had nearly twice the average rainfall.

STATISTICS OF THE SERVICES DIRECTORATE

The quantitative analyses in this section are intended to provide an indication of the distribution of work within the Directorate of Services and of the extent of the services provided.

TABLE I—NUMBERS OF OFFICES OF VARIOUS TYPES STAFFED BY THE METEOROLOGICAL OFFICE AND OPERATING ON 31 DECEMBER 1972

	Within U.K.	Overseas
Principal Forecasting Offices associated with the RAF	1	—
Main Meteorological Offices associated with the RAF	7	5
Subsidiary offices associated with the RAF	36	7
Observing offices associated with the RAF	6	3
Principal Forecasting Offices associated with civil aviation	1	—
Main Meteorological Offices associated with civil aviation	4	—
Subsidiary offices associated with civil aviation	11	—
Observing offices associated with civil aviation	7	—
Upper-air observing offices	8	5
Public service offices	6	—
CRDF offices	5	3
Port Meteorological Offices	6	—
Offices associated with the Agricultural Development and Advisory Service	3	—
Other offices	28*	3

* Four of these stations are administered by D.R.Met O

Notes

A Principal Forecasting Office meets the needs of aircraft flying over long distances and operates throughout the 24 hours.

A Main Meteorological Office operates throughout the 24 hours for the benefit of aviation and normally supervises the work of subsidiary offices.

A subsidiary office is open for that part of the day necessary to meet aviation requirements.

At an observing office no forecaster is available.

An upper-air observing office may be located with an office of another type if this is convenient.

Public service offices are located in certain large cities.

CRDF offices form the network for thunderstorm location.

Port Meteorological Offices are maintained at the bigger ports.

TABLE II—OCEAN WEATHER SHIPS

To meet its obligation under the ICAO North Atlantic Ocean Station Agreement the United Kingdom operates four Ocean Weather Ships which work in rotation with two ships from France, one ship from the Netherlands and two ships jointly operated by Norway and Sweden. The British ships serve at four of the five ocean weather stations in the eastern North Atlantic; each vessel makes, on average, eight voyages a year and spends an average of 24 days on station during each voyage. Some statistics for 1972 for the British Ocean Weather Ships are shown below.

Total number of days on station	722·7
Total number of days on passage	147·3

	Station A	Station I	Station J	Station K*
	average number per voyage			
Aircraft contacted	116	161	280	—
Number of aircraft given one or more radar fixes	68	118	206	—
Weather messages to aircraft	—	7	19	—

* During 1972 Station K was operated by France and the Netherlands.

TABLE III—MERCHANT NAVY SHIPS

A total of about 6700 ships of the merchant navies of the world make and transmit meteorological reports to the appropriate meteorological centres ashore under arrangements co-ordinated by the World Meteorological Organization. Most of them, including British ships, do this on a voluntary basis. Ships which report in full at four specified times daily are known as 'selected ships'; those which report at the same times daily, but in a less complete form, are known as 'supplementary ships'. A number of coasting vessels, light-vessels, distant-water trawlers and 'auxiliary ships' also make and transmit meteorological observations.

On 31 December 1972 the numbers of British ships reporting were:

Selected ships	504
Supplementary ships	48
	including 16 trawlers
Coasting vessels	59
Light-vessels	14
Trawlers	29
Auxiliary ships	23
Total	677

The British Voluntary Observing Fleet includes ships of many shipping companies, and the numbers on the various routes are as follows:

U.K. to Australasia	73
U.K. to Far East	76
U.K. to Persian Gulf	36
U.K. to South Africa	55
U.K. to West Indies	32
U.K. to Atlantic coast of North America	84
U.K. to Pacific coast of North America	8
U.K. to South America	19
U.K. to European ports	39
U.K. to Falkland Islands and Antarctica	2
U.K. to distant-water fishing grounds	21
World-wide tramping	107

During two typical days, one in June, the other in December, the numbers of reports from ships received in the Central Forecasting Office were as follows:

	Reports *June*	Reports *December*
Direct reception from:		
British ships in eastern North Atlantic	92	107
Foreign ships in eastern North Atlantic	38	17
British trawlers in North Sea	16	12
British merchant ships in North Sea	45	54
Total	191	190
Reception via other European countries:		
Ships in eastern North Atlantic	367	277
Ships in Mediterranean	54	69
Ships in North Sea	116	137
Ships off north Russia	19	29
Ships in other European waters	12	22
Ships in Pacific	41	3
Total	609	537
Reception via U.S.A. and Canada		
Ships in North Atlantic	432	428
Ships in North Pacific	647	867
Ships in other waters	36	30
Total	1115	1325

TABLE IV—CLASSIFICATION OF STATIONS RENDERING CLIMATOLOGICAL RETURNS

A large amount of meteorological data is obtained for climatological purposes from stations which are not part of the Meteorological Office organization. The following table shows how the sources of climatological information in the United Kingdom (including Meteorological Office stations) were distributed on 31 December 1972.

	Stations Supplying Returns					Autographic Records		
	Observatories	*Synoptic*	*Agrometeorological*	*Climatological*	*Rainfall**	*Sunshine*	*Rainfall*	*Wind*
Scotland, north	1	9	0	31	327	27	11	13
Scotland, east	0	10	9	62	624	52	22	11
Scotland, west	1	15	1	52	536	29	25	17
England, north-east	0	10	5	23	514	27	20	12
England, east	0	11	14	21	562	31	18	11
England, Midlands	0	14	17	46	1348	59	24	16
England, south-east (including London)	1	18	19	44	877	63	26	16
England, south-west	0	15	8	35	564	35	8	8
England, north-west	0	6	3	20	513	24	14	12
Wales, North	0	2	3	15	291	11	4	2
Wales, South	0	7	9	15	392	22	4	4
Isle of Man	0	2	0	1	19	3	1	2
Isles of Scilly and Channel Isles	0	3	0	4	21	7	0	2
Northern Ireland	0	6	7	51	304	29	40	8
Total	3	128	95	420	6892	419	217	134

* Includes stations in earlier columns

TABLE V—HEIGHTS REACHED IN UPPER AIR ASCENTS

The following table shows the number of upper air ascents giving observations of (a) temperature, pressure and humidity and (b) wind, which have reached specified heights, and the height performance of the largest balloons.

(a) Observations of temperature, pressure and humidity

	Number of observations	Percentage of all balloons reaching				Percentage of largest balloons reaching
		100 mb 16 000 m (approx.)	*50 mb 20 000 m (approx.)*	*30 mb 24 000 m (approx.)*	*10 mb 30 000 m (approx.)*	*10 mb 30 000 m (approx.)*
Eight stations in the U.K.	5846	95·2	82·6	53·9	6·9	29·3
Five stations overseas	3159	97·1	82·9	52·7	4·2	58·2
Four Ocean Weather Ships	1494	94·2	78·9	47·9	1·1	—

(b) Observations of wind

	Number of observations	Percentage of all balloons reaching				Percentage of largest balloons reaching
		100 mb 16 000 m (approx.)	*50 mb 20 000 m (approx.)*	*30 mb 24 000 m (approx.)*	*10 mb 30 000 m (approx.)*	*10 mb 30 000 m (approx.)*
Eight stations in the U.K.	11 605	88·8	68·0	31·5	3·1	25·9
Five stations overseas	5 202	88·2	69·5	37·3	2·4	55·3
Four Ocean Weather Ships	2 973	89·5	65·2	32·8	0·9	—

TABLE VI—THUNDERSTORM LOCATION

Number of thunderstorm positions reported by CRDF network:
In 1972 .. .. .. 57 348

TABLE VII—METEOROLOGICAL COMMUNICATIONS TRAFFIC

Almost all the national and international exchanges of meteorological data which are used in the construction of synoptic charts and the production of forecasts are effected by coded messages. The coded messages are composed of groups of five figures and there may be from 5 to 90 such groups in one message. The messages are exchanged by radio and land-line facilities. In addition there is an exchange, both nationally and internationally, of meteorological information in pictorial format. This information is largely analyses and forecasts derived from processing observational data. The transmission method is analogue facsimile by either radio or land-line.

The following figures give an analysis of the traffic (mainly coded messages and information in pictorial format) through the Meteorological Office Telecommunication Centre, Bracknell, for one typical day (24 hours) taken in November 1972 and, for comparison, some corresponding figures are given for one day near the end of 1971.

	In	Out	Total	Total in 1971
Coded messages		*number of groups in one day*		
Land-line teleprinter	532 233	378 945	911 178	878 150
Radio	200 389	247 176	447 565	403 811
Facsimile charts (pictorial format)		*number of charts in one day*		
Land-line	98	789	887	851
Radio	65	144	209	199

TABLE VIII—SPECIAL SEASONAL FORECASTS

There is a need for forecasts of a special type at certain seasons. These are detailed in MetO Leaflet No. 1 (1970). The numbers receiving such specialized services are as follows:

	Year	No. of customers	Year	No. of customers
Fine-spell notifications (a summer service primarily for farmers)	1971	265	1972	223
Week-end temperature forecasts (a winter service primarily for industrialists) ..	1971–72	27	1972–73	27
Winter road danger warnings (primarily for local authorities)	1971–72	416	1972–73	422

TABLE IX—FORECASTS FOR AVIATION

Forecasting for aviation constitutes the primary function of many of the offices. The Central Forecasting Office is mainly concerned with analysis of the weather situation, the issue of guidance in outline to other offices and the issue of forecasts to the BBC and the national Press. Thus the volume of work in the Central Forecasting Office shows little variation from year to year. The following figures indicate the numbers of forecasts issued for aviation and the numbers of meteorological briefings that took place during 1971 and 1972. They do not include warnings and routine general forecasts.

	1971	1972
Number of meteorological briefings for		
aviation in the U.K.	395 537	414 748
aviation at overseas stations	40 266	36 868
Number of aviation forecasts issued for ..		
aviation in the U.K.	1 110 115	1 338 820
aviation at overseas stations	289 411	192 723

Note:

The fall in the totals for overseas stations is largely explained by the closure of forecasting offices in the Far East and in the Persian Gulf during the latter part of 1971.

TABLE X—NON-AVIATION INQUIRIES

Non-aviation inquiries are handled by five Weather Centres, in London, Manchester, Glasgow, Southampton and Newcastle, and one other office in Nottingham (Watnall) whose function is to meet the needs of the general public for forecasts for special purposes. Many other forecast offices, established primarily to meet the needs of aviation, also answer requests for forecasts and other weather information from the general public, Press, public corporations, commercial firms, etc. (The *Post Office Guide* lists 37 offices providing forecasts for the general public.) These inquiries, most of which refer to current or future weather, are listed below according to the purpose of the inquiry.

	1971	1972
Total number of non-aviation inquiries	1 535 523	1 582 129
Percentage relating to		
agriculture	9·3	9·6
building	5·3	5·0
commerce, industry	4·7	5·0
holidays	21·0	21·0
marine matters	15·9	16·2
Press	10·1	10·7
public utilities	8·2	9·1
road transport	9·8	9·3
other known purposes	6·9	6·7
unknown purposes	8·8	7·4

TABLE XI—FLASH WEATHER MESSAGES

FLASH weather messages are passed to the BBC for broadcast on radio, and to the BBC and most Independent Television Companies for inclusion in their programmes at a convenient break. They are, effectively, warnings of the actual occurrence of weather conditions which might cause considerable inconvenience to a large number of people. The following table shows the kind of weather and areas of the country for which FLASH messages are broadcast and the number issued in 1972.

Area	Dense fog	Heavy rain	Glazed frost or icy roads	Severe inland gales
Edinburgh and south-east Scotland	—	—	—	—
Glasgow and south-west Scotland	—	—	—	1
Belfast and Northern Ireland	2	—	1	—
Industrial north-east England	—	—	—	—
Industrial Lancashire and Merseyside	1	—	—	—
Industrial Midlands	—	2	—	1
Bristol and Bath	—	2	—	1
South Wales	—	2	—	1
London and south-east England	1	—	—	—
Plymouth and south-west England	—	6	—	2
Yorkshire	1	2	—	—
Southampton and Portsmouth	1	1	—	1
Total	6	15	1	7

TABLE XII—AUTOMATIC TELEPHONE WEATHER SERVICE FORECASTS

The total number of calls made on the service during 1972 showed an increase of 11·3 per cent over the previous year.

Forecasts were available at 54 Post Office Information Centres for 25 forecast areas.

Information Service Centre	Forecast area	Number of calls 1971	1972
Bedford	40 miles radius of Bedford	115 340	161 342
Belfast	Belfast	143 991	180 158
Birmingham	Birmingham	444 799	598 141
Blackburn	Central Lancashire	110 026	140 041
Blackburn	Lancashire coast	52 792	65 864
Blackpool	Lancashire coast	136 604	148 665
Bournemouth	South Hampshire	158 331	196 911
Bradford	Leeds, Bradford, Huddersfield	70 218	87 438
Brighton and Hove	Sussex coast	471 658	449 781
Bristol	Bristol	560 070	477 711
Cardiff	Cardiff	278 793	385 268
Canterbury	Kent coast	157 497	171 205
Chelmsford	Essex coast	76 663	85 578
Cheltenham	South-west Midlands	61 868	71 485
Chester	Chester and North Wales coast	86 476	116 056
Colchester	Essex coast	189 136	185 314
Colwyn Bay	Chester and North Wales coast	48 547	64 006
Coventry	Birmingham	80 235	99 934
Derby	Nottinghamshire, Derbyshire, Leicestershire	98 356	110 029
Doncaster	Sheffield, Chesterfield, Doncaster, Barnsley	28 137	29 501
Edinburgh	Edinburgh	222 365	279 071
Exeter	South Devon and east Cornwall	95 857	112 668
Glasgow	Glasgow	362 490	450 266
Gloucester	South-west Midlands	98 698	134 430
Guildford	London	75 979	81 773
Hereford	South-west Midlands	35 752	61 707
Huddersfield	Leeds, Bradford, Huddersfield	39 024	53 324
Leeds	Leeds, Bradford, Huddersfield	196 809	249 108
Leicester	Nottinghamshire, Derbyshire, Leicestershire	224 830	245 923
Lincoln	North Lincolnshire and Retford area	20 864	23 366
Liverpool	South Lancashire and north Cheshire	191 089	197 741
Liverpool	Lancashire coast	65 055	69 341
Liverpool	Chester and North Wales coast	52 194	56 172
London	London	2 747 974	2 663 985
London	Essex coast	155 622	142 762
London	Kent coast	160 377	162 925
London	Sussex coast	307 773	316 387
London	Thames Valley	159 366	139 995
London	40 miles radius of Bedford	73 975	74 860
Luton	40 miles radius of Bedford	67 083	95 924
Manchester	South Lancashire and north Cheshire	269 765	330 995
Manchester	Lancashire coast	68 551	84 984
Manchester	Chester and North Wales coast	49 445	68 529
Medway	Kent coast	72 133	103 213
Middlesbrough	Tyne, Tees	96 609	115 453
Newcastle	Tyne, Tees	216 258	261 647
Nottingham	Nottingham, Derbyshire, Leicestershire	410 221	414 415
Oxford	Thames Valley	167 563	165 984
Peterborough	40 miles radius of Bedford	47 658	48 177
Plymouth	South Devon and east Cornwall	135 892	186 555
Portsmouth	South Hampshire	257 842	286 447
Reading	Thames Valley	227 334	224 515
Sheffield	Sheffield, Chesterfield, Doncaster, Barnsley	192 347	218 644

TABLE XII (*continued*)

Information Service Centre	Forecast area	Number of calls 1971	Number of calls 1972	Date of opening
Southampton	South Hampshire	259 074	328 244	
Southend	Essex coast	117 716	141 195	
Southport	Lancashire coast	41 385	50 024	
Swindon	Bristol	30 946	32 235	
Torquay	South Devon and east Cornwall	55 999	75 583	
Tunbridge Wells	London	45 540	44 807	
Bishops Stortford	40 miles radius of Bedford	10 197	24 060	April 1971
Grimsby	North Lincolnshire and Retford area	17 187	34 353	May 1971
High Wycombe	Thames Valley	14 849	44 845	July 1971
Ipswich	Norfolk and Suffolk	8 856	59 850	September 1971
Norwich	Norfolk and Suffolk	18 331	79 878	September 1971
Total		11 554 411	12 860 788	

TABLE XIII—CLIMATOLOGICAL INQUIRIES

Met O 3, Met O 8, Edinburgh and Belfast receive a number of inquiries relating to past weather to climatology and to the application of meteorological data to agriculture. The following figures give the total number of inquiries and the percentages of this number in various categories.

	1971	1972
Total number of climatological inquiries	13 553	15 269
Percentage relating to		
agriculture (farming, forestry, market gardening)		11·5
building and design (including siting)		18·7
commerce (sales, marketing, advertising)		5·1
drainage		1·6
education and literature		6·2
flooding		0·3
heating and ventilation		2.2
industrial and manufacturing actitivities		4·7
law (damage, accident, insurance)		15·0
medical and health		1·3
Press and information centres		3·4
research		7·5
sport, hobbies, holidays		1·5
transport and communications		1·5
water supplies		7·7
miscellaneous (purpose known)		5·1
miscellaneous (purpose unknown)		6·7

TABLE XIV—DATA PROCESSING

(a) Punched-card installation

Number of cards punched by the Meteorological Office installation	1 395 194
Number of cards punched elsewhere on behalf of the Meteorological Office ..	241 465
Number of cards converted from paper tape	435 187
Number of non-routine investigations completed	158

(b) Computer installations

(1) The KDF9 computer (COMET) was used for computing during 5114 hours.

(2) The 360/195 computer was used for computing during 7362 hours.

TABLE XV—INSTRUMENT TESTING AND CALIBRATION

The numbers include those of instruments tested or calibrated for outside authorities on repayment.

	Number of tests or calibrations
General meteorological instruments	20 635
Balloons	61 320
Radiosonde batteries	29 706
Radar reflectors	25 050
Electrical/electronic instruments	531
Electrical/electronic components	21 802
Radiosondes, calibrated	17 598
Total	176 642

In addition, 2392 radiosondes were recovered after flight and 54 per cent of these were repaired and recalibrated for further use.

THE DIRECTORATE OF RESEARCH

Special Topic—Research on Numerical Forecasting

Since the 1930s the forecasting of weather, winds and temperatures for up to a few days ahead has been a two-stage process. First the pressure and temperature fields are predicted for the time to which the forecast refers, the winds being easily deduced from these patterns in extratropical regions by means of the geostrophic-wind approximation. The geostrophic assumption requires that the air does not accelerate and therefore blows parallel to the isobars and is directly proportional in speed to the pressure gradient. A rather better approximation to the wind can be obtained by allowing for acceleration due to curvature of the airflow. The second stage of the forecast process is the interpretation of the patterns of pressure and temperature in terms of weather such as rain, cloud and fog etc. These forecasts are basically subjective, extrapolation and the experience of the forecaster playing a large part in their production. The fundamental laws of dynamics and physics were beginning to be used in a qualitative way by the middle of the century, e.g. the development theory of R. C. Sutcliffe.[1] Within the last 10 years numerical methods of forecasting the pressure and temperature patterns have been gradually introduced into the operational units of many national meteorological services.

The earliest attempt to predict the future state of the atmosphere by solving numerically the usual equations of hydrodynamics and thermodynamics that apply to compressible fluids was made by L. F. Richardson[2] at the end of the First World War. The attempt ended in failure owing to lack of an adequate knowledge of the initial state of the atmosphere and insufficient knowledge of correct methods of obtaining approximate numerical solutions to the complicated non-linear mathematical equations which describe the behaviour of the atmosphere. Nevertheless the basic equations derived by Richardson are similar to those used today in numerical weather prediction. During and after the Second World War the number and quality of upper-air observations increased and, with the advent of modern electronic computing machines, research restarted into numerical methods of weather prediction.

Twenty years ago computers were more than ten thousand times slower than the fastest present-day computers and it was necessary considerably to simplify the basic equations in order to obtain solutions in a reasonable time. One of the fundamental approximations used in the early numerical models was the use of the geostrophic wind. As the geostrophic wind can be derived directly from the pressure field this reduces the number of dependent variables and at the same time gives a filtering effect which removes small-scale irregularities which are also possible solutions of the basic equations, thus allowing a larger time-step to be used in the integrations than would otherwise be possible. The first models only attempted to predict variations at one level in the atmosphere, and this was the approximately non-divergent level in mid troposphere at about 5000 metres above mean sea level. The method used involved the conservation of absolute vorticity and ignored physical processes such as friction, the release of latent heat and the existence of horizontal temperature gradients which are clearly important in the behaviour of the atmosphere. Nevertheless, the results were sufficiently encouraging to stimulate

further research and, as the speed of the computers increased, models were developed which corresponded more and more closely to the real atmosphere. More than one representative level in the vertical was introduced, allowing the effects of horizontal temperature differences to be represented and more and more physical processes were included, albeit in a very approximate manner. Numerical integration schemes were devised which made the filtering approximation of the geostrophic wind unnecessary and, as third- and fourth-generation computers became available, models were formulated which used the equations of motion, thermodynamics and continuity in their fundamental form. The removal of the geostrophic approximation, which is inconsistent with vertical motion, has allowed some physical processes such as the release of latent heat to be represented in a more direct way than has hitherto been possible. In 1965 a 3-level quasi-geostrophic model was introduced into operational use in the Meteorological Office and in August 1972 this was replaced by a 10-level primitive-equation model.

Since 1965 the Forecasting Research Branch of the Office has been developing two versions of the Bushby–Timpson[3] 10-level primitive-equation model. The calculations are based upon the values of the atmospheric variables (pressure, temperature, wind etc.) at the corners of a network of points. Two different meshes are used. The coarse-mesh version, recently introduced into operational use, has a grid spacing of about 300 km at 60° N, and covers an octagonal area circumscribing 15° N, whilst the fine mesh uses a grid length one-third that of the coarse mesh and covers the area shown in Figures 4–8. It is necessary to use a time-step of 200 seconds for the coarse mesh and 75 seconds for the fine mesh and even with the powerful IBM 360/195 computer recently installed at Bracknell it takes 36 minutes to compute a 72-hour forecast for the octagon and 48 minutes to compute a 36-hour forecast for the fine-mesh area. Moreover, these times do not include the very necessary data-preparation and analysis which has to take place before the integrations can start. In this model pressure is used as the vertical co-ordinate and the state of the atmosphere at any given time is represented by values of wind (two components), humidity, and the geopotential height of a pressure surface at each of the grid points for each of the 10 pressure levels from 1000 to 100 mb at 100-mb intervals. In order to obtain the initial values of these dependent variables at grid points it is necessary to interpolate them between the values reported at observing stations. The objective analysis of contour heights is currently performed at Bracknell by fitting by the method of least-squares a quadratic surface to observed and forecast values in the vicinity of a grid point and repeating this process at each grid point in turn. In analysing the heights of pressure surfaces it is possible to make use of wind as well as height observations as the geostrophic and gradient-wind approximations relate winds to gradients of heights of the pressure surfaces. The analysis of humidity is more difficult as humidity patterns are much more localized, being on the scale of warm and cold fronts rather than of anticyclones and depressions. There is no other observation which can help the analysis in the direct way that wind observations help the analysis of the pressure field although methods of incorporating surface reports of weather and cloud into the upper-air analysis of humidity are being investigated. Humidity patterns, self-consistent with the vertical motion, are soon produced by the forecast model and the objective analysis of humidity is obtained by using a weighted mean of observed values and those obtained from a recent forecast,

more weight being attached to the forecast values than when the pressure field is being analysed. The observed wind fields are not analysed independently as this would produce troublesome gravity waves due to imbalance with the contour-height fields. As stated previously, the winds are used to obtain the best-possible contour-height analysis and then a complicated set of non-linear partial differential equations are solved in order to obtain initial wind fields which are in balance with the mass field.

The physical processes represented in the model include the latent-heat effects of condensation and evaporation of water, and an ice phase has recently been introduced. When supersaturation occurs in any layer, then rain (or snow) is allowed to fall into the layer below and, if there is no layer below, precipitation is forecast to reach the ground. In the atmosphere, small-scale convection such as can be seen by the formation of cumulus and cumulonimbus cloud takes place when the atmosphere becomes statically unstable, thus tending to restore the atmosphere to neutral equilibrium. It is necessary to parameterize this sub-grid-scale effect in the model and a scheme has been developed which examines each vertical column at each time-step of the forecast and allows vertical mixing, sometimes producing convective rainfall, if vertical instability occurs. Another important physical process which has been incorporated in the model is the exchange of energy between the earth's surface and the atmosphere (Gadd and Keers[4]). The oceans are assumed to provide an infinite heat source and the amounts of sensible and latent heat transferred into the atmosphere are a function of the sea surface temperature and the wind, temperature and humidity of the lowest layer of the model atmosphere. Over land, the amount of incoming radiation is evaluated, allowing for the presence of clouds which are estimated from the forecast humidity structure; calculations are then made as to how much of this energy is available for retransmission to the atmosphere as sensible and latent heat. Friction and topography are also included.

An example of a 36-hour forecast on the fine mesh is shown in Figures 4–8. The main feature of the synoptic situation during this period was the movement over the British Isles of the low-pressure trough associated with an occluding warm sector. This, together with the associated rain patterns, was quite well forecast. Figure 6 shows the frontal rain to be forecast from Scandinavia across the southern part of the British Isles in quite good agreement with the actual chart (Figure 5) with patches of rain (of a convective nature) forecast in the cold air behind the fronts where showers were actually occurring. Figure 7 shows the rain belt as having cleared the country twelve hours later, and this was forecast (Figure 8) with a few showers in the cold air. The rain areas associated with the deepening Atlantic depression were forecast in reasonable agreement with the observations even though the central pressure of the disturbance was in error at 36 hours by 15 mb. The anticyclone over the eastern Atlantic was also well forecast to remain quasi-stationary even though the central pressure was a few millibars too low.

Even though the coarse-mesh version of the model is already being used operationally, and it is likely that the fine-mesh version will shortly become operational, research is still continuing on ways in which the model can be improved. Experiments are being conducted to develop better representation of the physical processes which occur in the atmosphere and to reduce the tendency for features of the predicted weather charts to move too slowly—a

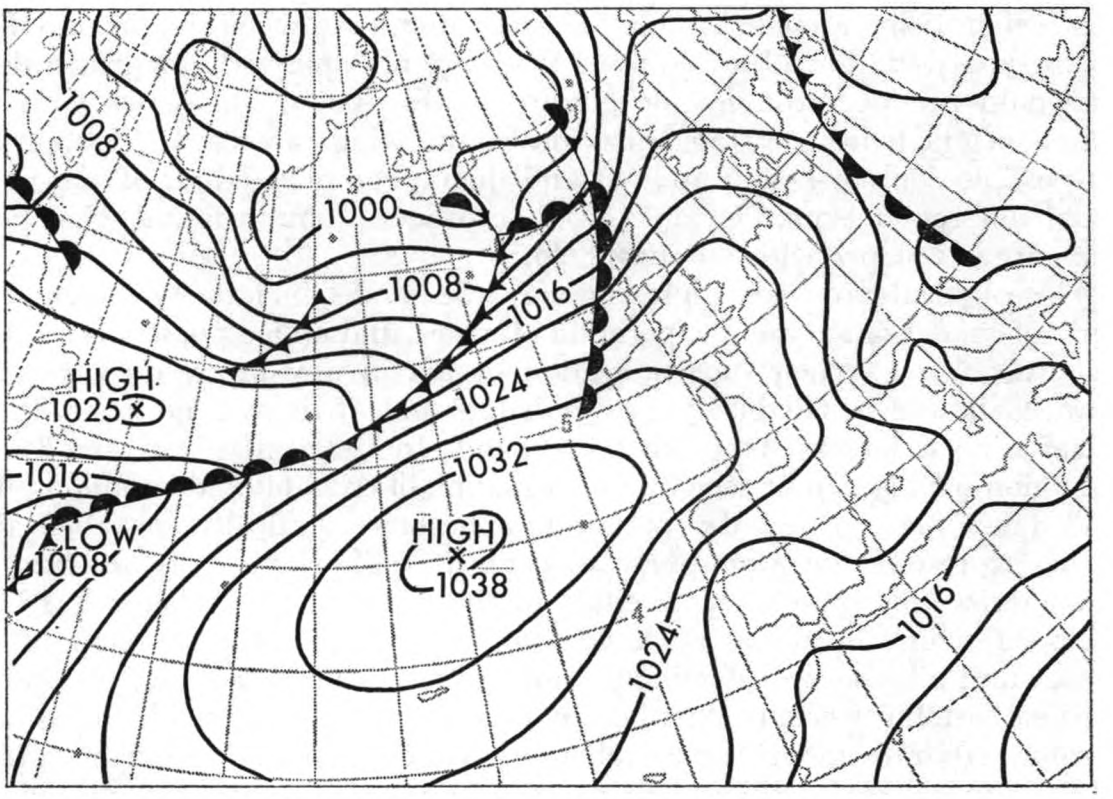


FIGURE 4—INITIAL SURFACE CHART FOR 12 GMT 16 AUGUST 1972

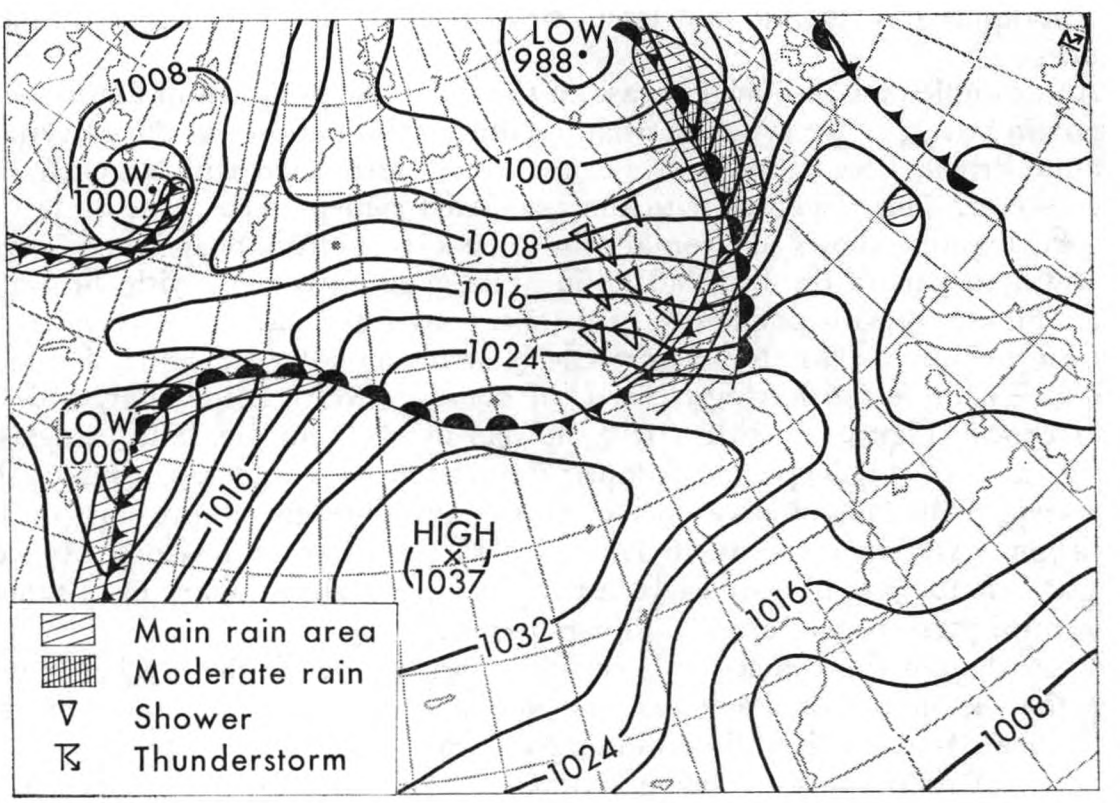


FIGURE 5—SURFACE CHART FOR 12 GMT 17 AUGUST 1972

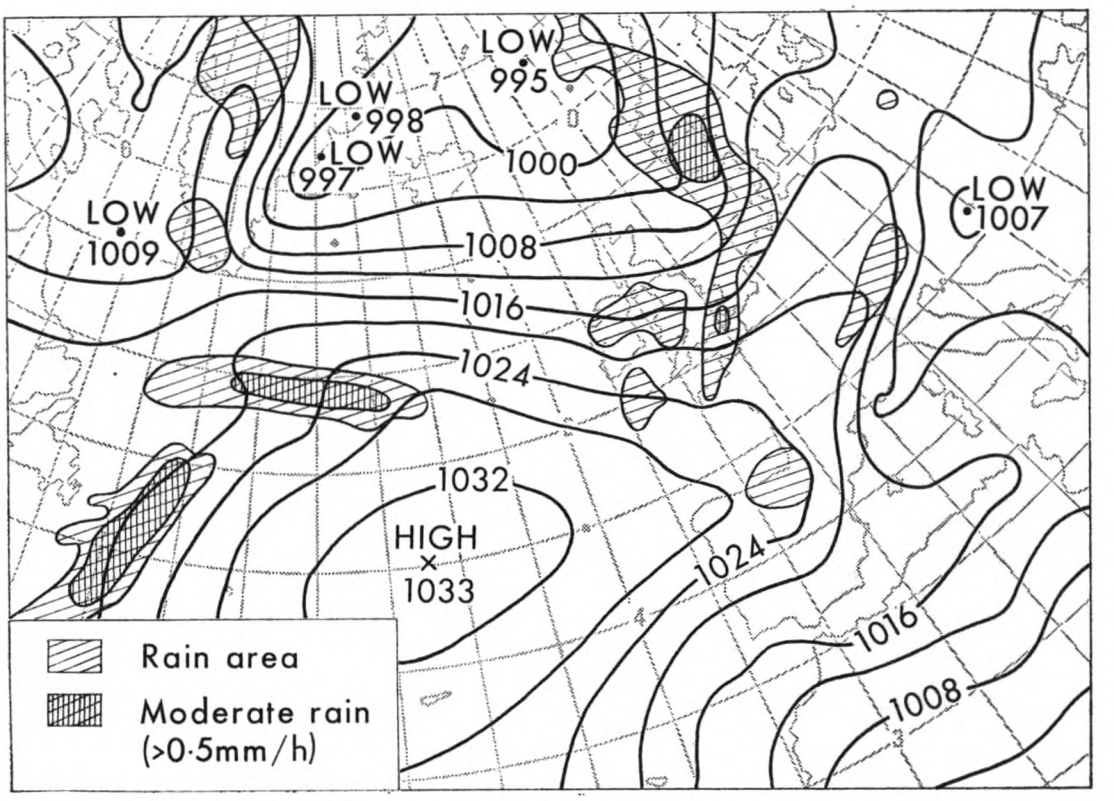


FIGURE 6—SURFACE 24-HOUR FORECAST (10-LEVEL MODEL) FOR 12 GMT 17 AUGUST 1972

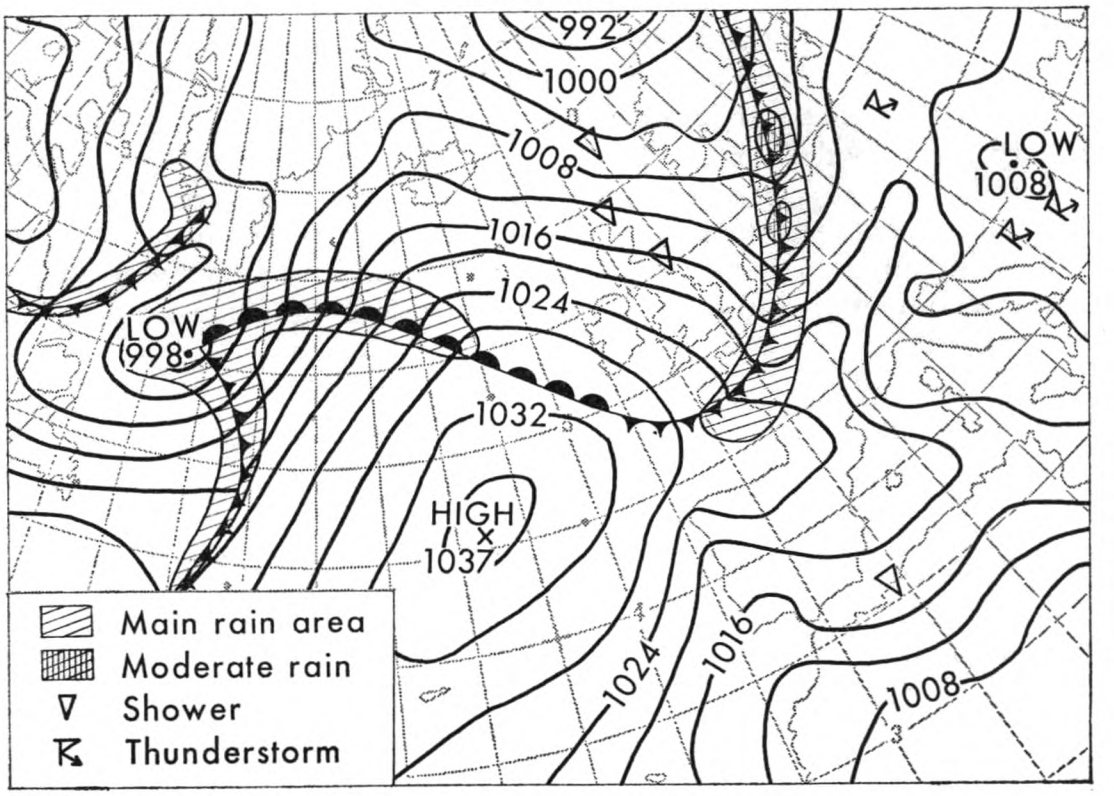


FIGURE 7—SURFACE CHART FOR 00 GMT 18 AUGUST 1972

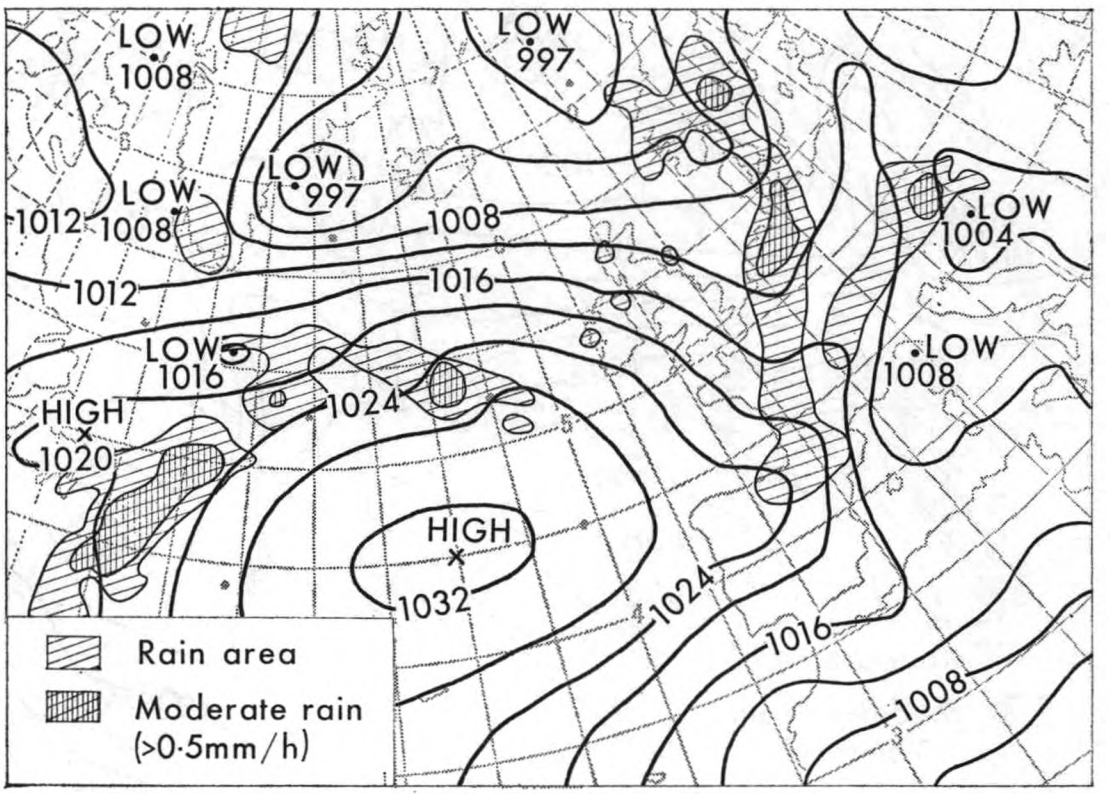


FIGURE 8—SURFACE 36-HOUR FORECAST (10-LEVEL MODEL) FOR 00 GMT 18 AUGUST 1972

fault which is inherent in most simple arithmetic integrations of mathematical equations. In addition a new method of solving the equations is being developed, which if successful is likely to reduce the time of the integrations by a factor of about three. Work has just commenced on the development of a new planetary boundary layer model for the British Isles with a horizontal grid length of 10 km and about 10 levels from the surface to 2 km. The purpose of this is to enable the nature of the underlying surface to be represented in sufficient detail for the prediction of mesoscale weather phenomena. This model will eventually be run in conjunction with a large-scale model, from which the top boundary conditions will be obtained.

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Physical Research

Droplets and ice particles in clouds

Despite world-wide research there is still a lack of understanding of some aspects of the growth of droplets and ice particles which are critical for the full understanding of the formation of rain. Research was continued both on the growth of droplets in a turbulent environment and on the production of minute ice crystals.

Experiments have been conducted which demonstrate that the frequency with which droplets amalgamate by collision is enhanced in the presence of a wind shear, but the physical processes leading to this enhancement are still obscure. The effects of turbulent mixing on the growth of droplets has also been studied by mathematical simulation of the processes on a computer. Mixing leads to an interchange of droplets from within the cloud with nuclei from outside. However, although the subsequent competition for available water leads to an increase in the preferred size of the remaining droplets, the calculated number of drops with radius between 1 and 10 μm is less than observations in clouds suggest. The time taken for a given concentration of large drops to grow from a typical distribution of smaller droplets is less in turbulence than in still air (only about half the time is needed). The spectrum of drop sizes also has a much wider spread when coalescence and condensation processes are modelled in turbulence rather than in still air.

Measurements of ice-particle concentration in natural clouds generally are known to show satisfactory agreement with the measured number of ice nuclei in certain stratiform clouds and continental cumulus clouds. However, in cumuli of maritime origin, the ice-particle concentration may exceed that of the nuclei by a factor of 10^4 at temperatures near -10°C. The nature of this apparent discrepancy is being studied in the laboratory. A series of experiments has been started to study the possibility that, when water droplets freeze in free fall or on riming, very small particles of ice are ejected which could significantly influence the ice budget and precipitation growth in supercooled clouds. Previous experiments had shown that, under conditions close to those in the atmosphere, the ejection of ice splinters was a rare phenomenon. However, these experiments were only capable of detecting comparatively large ice splinters of over 5 μm radius. Preliminary results of the current study show that particles smaller than 0·1 μm can be ejected during riming and the studies are continuing to see whether this mechanism is important in conditions representative of those in atmospheric clouds.

In order to pursue studies of microphysical processes in cloud, effort is being devoted to the development of appropriate instruments for equipping the C 130 aircraft shortly to be delivered to the Meteorological Research Flight. This instrumentation will provide for the measurement of droplet sizes and the distribution of droplets in space within clouds. Instruments for the measurement of electric field strength, conductivity and droplet charge are also being developed in co-operation with the University of Manchester Institute of Science and Technology and these have undergone successful preliminary testing on board the Varsity aircraft.

Cloud structure

The data obtained during Phase III of Project Scillonia have yielded important information on the banded structure of the precipitation area in the

frontal system which passed through the Isles of Scilly during 18 January 1971. There is good agreement between the precipitation structure revealed by the 43S radar and the vertical velocity distribution calculated from the observed horizontal wind field obtained by following radar targets dropped from aircraft. The dominant rain-bands which were found to be orientated parallel to the surface cold front, were typically 100 km wide, and moved somewhat faster than the underlying warm front. The bands were characterized by clusters of weak small-scale convective cells resulting from the potential instability produced where tongues of relatively dry air overran low-level moist air which was beginning its slantwise ascent above the warm-frontal zone.

Studies have been conducted with a view to determining whether it is practicable to develop dropsonde systems which will enable similar studies of rain areas to be continued without being dependent on ground-based radar. This would give much greater flexibility in selecting rain systems for examination, and permit the extension of the area explored. A new aircraft dropsonde has been planned. The position and motion of the sonde (and hence the wind) will be determined from a radio-navigation system. It has been demonstrated that wind determinations of sufficient accuracy can be achieved over the North Atlantic. The required accuracy in height determination appears to be possible by using a simple radio-altimeter. Meteorological sensors to determine temperature and humidity, and also to detect the presence of cloud are under development.

Fog

A series of field experiments is being conducted at Cardington in collaboration with the Atomic Energy Research Establishment at Harwell. The aim is to measure as completely as possible the various physical changes and processes occurring during a period of radiation fog. Data obtained during a successful experiment on 17 December 1971 have revealed a wealth of phenomena of physical interest. It has been possible to account broadly for the observed heat- and water-budgets of the fog, although inconsistencies in detail require to be resolved. The observations have indirectly revealed significant aspects of the nature and intensity of the turbulence. Mathematical studies of the processes are being initiated in support of the project which is being continued on suitable occasions during the fog season 1972/73.

Oceanography

The studies of the upper layers of the sea which had been conducted over several years by Dr J. D. Woods were wound up when he gave up his research fellowship to become Professor of Oceanography at Southampton University. Dr Woods's researches are described in earlier *Annual Reports* and his valuable work on the structure of the thermocline will continue at Southampton.

Radar meteorology

An observational study of clear-air turbulence (CAT) was mounted with the objective of obtaining simultaneous measurements by the high-power radar at Defford and by an aircraft of the Meteorological Research Flight within the same patch of high-altitude turbulence. The aim was to learn more about the fine-scale structure and mechanism of CAT and to establish relationships between turbulence intensity, radar reflectivity, Doppler characteristics and

billow amplitude. The high-powered Defford radar detected the characteristic billow echoes associated with CAT on several occasions during some of which the billows were sufficiently persistent to enable the Meteorological Research Flight Canberra to be flown through them. Detailed analysis is in progress of data obtained on 10 May 1972.

In August a programme was undertaken using the Defford radar in co-operation with the Meteorological Research Unit, Cardington, the Radio and Space Research Station, Slough, and Reading University. The aim was to study the structure of convection in the atmospheric boundary layer and its effect on the overlying stable layer. Data obtained should reveal the distribution of temperature and vertical velocity within convective elements although the diffuse nature of the radar echo patterns and the occurrence of widespread contaminating echoes, presumed to be from insects and birds, may be a limiting factor in the use of radar for this purpose at this time of the year.

An analysis has been started of autographic rain-gauge records obtained on known occasions of rain-swathes downwind of the South Wales mountains, and a two-month observational programme began in October in which radars were used to observe the evolution of the three-dimensional structure of precipitation patterns as they travel from the sea, over the Welsh mountains, and into the Midlands. It is hoped thereby to gain more insight into the orographic effects on precipitation.

A small expert team at the Royal Radar Establishment has made a study of the processing, transmission and display system which will be required for any future network of linked weather radars. Plans are being drawn up to experiment with a small network of two or three radars to study the behaviour of rain systems over a wider area than is possible from a single site.

Studies related to air pollution

A pollution monitoring station is being established at Lerwick as part of the World Meteorological Organization network for recording the background pollution of the atmosphere in areas remote from local sources of pollution. Currently effort is being devoted to the evaluation of the collection and retention efficiency of air- and rain-sampling equipment.

As part of a national programme co-ordinated by the Department of the Environment, the feasibility has been demonstrated of measuring from an aircraft the large-scale distribution of sulphur dioxide. The sampling and analytical techniques were provided by the Atomic Energy Research Establishment (AERE), Harwell, and the flights were conducted by the Meteorological Research Flight. A programme is now being undertaken to study the development of the vertical profile of sulphur dioxide in air downwind of the industrial areas of the country, especially off the east coast and out over the North Sea. From the data which will be obtained it is hoped to establish the significance of the absorption of sulphur dioxide at the surface. Other information on this process is being obtained from measurements of the low-level vertical profiles of wind, temperature and sulphur dioxide, in conjunction with AERE, Harwell. The latter type of data may be used to estimate deposition of sulphur dioxide, by the technique familiar in estimating evaporation from a natural surface. A practical scheme for forecasting day-to-day variations in the sulphur dioxide content of the air in London was developed and introduced at London Weather Centre.

A study is being made of means of monitoring the stratospheric aerosol with a view to determining the role, if any, that artificially injected particles from fleets of supersonic transport aircraft might have on the radiation balance. Rather than measure the properties of the particles directly, consideration is being given to the direct measurement of the absorption of solar radiation by particulates as distinct from the extinction by scattering.

The atmospheric boundary layer

A wide range of applications of meteorology depend upon an understanding of the transport of heat, moisture, momentum and material through the lower layers of the atmosphere by turbulent air motions. The Meteorological Office maintains both theoretical and observational studies of these processes. Facilities at Cardington provide for measurement of profiles of wind, temperature and humidity, and of the transport processes from the lowest few metres through the whole of the atmospheric boundary layer. The measurements at higher levels are made from the cables of large captive balloons. Scientific staff at Porton engage in the general research studies as well as providing the meteorological assistance required by the Chemical Defence Establishment and the Microbiological Research Establishment.

Comparisons of the Cardington captive-balloon equipment with the measuring techniques of the U.S. Air Force Cambridge Research Laboratories were carried out during field trials in the United States in 1971. These have now been completely evaluated. The results confirm that the Cardington equipment may be used to measure vertical fluxes without incurring important errors from the movement of the balloon cable. Development of the radiotelemetry system for use with this equipment has been completed and as soon as these systems are received from the manufacturers it will be possible to proceed with multi-level studies of turbulence and eddy flux throughout the whole depth of the boundary layer. More rapid progress will then be possible in the basic appreciation of the action of the boundary layer. The experimental and theoretical studies of the boundary layer are being turned increasingly to problems which are of practical interest or important for the development of other aspects of meteorology. The studies in regard to fog, air pollution and the radar probing of the stable cap of the boundary layer have already been mentioned in preceding paragraphs. Studies are also in progress on the breakdown of the nocturnal inversions, the warming of air flowing over relatively warm sea, the methods by which boundary effects should be introduced into numerical forecasting procedures and the methods by which, for climatological and forecasting purposes, the intensity and depth of mixing may be represented as a function of the broad meteorological conditions.

The Meteorological Office has co-operated with university groups in the Joint Air Sea Interaction (JASIN) experiment organized by a Royal Society working group. Appropriate instrumentation and an observer were provided during the course of the three-ship observational programme near Ocean Weather Station Juliett during the summer. Studies of the boundary layer over the sea have been extended to include experimental measurements of sea-spray and the study of its role in the transfer of moisture to the atmosphere.

Closure of the research unit at Cambridge

The small research station which had been making micrometeorological

studies in conjunction with the Plant Breeding Institute and University Department of Agriculture at Cambridge during the growing season of crops was closed in April. The station which had been in operation since 1946 had made pioneering studies of evaporation, soil moisture, temperature and humidity profiles in the crop environment. With the technique now fully established it is appropriate that these studies should be continued, when required, by the agricultural research teams concerned rather than by the Meteorological Office.

High atmosphere

The major part of the effort this year has been concentrated on the assessment and preparation for publication of the results gained in earlier years by SKUA rocket soundings. Several soundings were made from South Uist in the early months of the year to continue the investigations of stratospheric warmings. The characteristics of the 1971/72 winter differed considerably from the previous winter in this respect. A second tracking radar has been installed at South Uist to operate in conjunction with a newly developed payload designed to eject wind-following targets as well as the parachute-sonde to extend the observation of upper stratospheric winds to about 80 km. Investigation of methods for the economic extension of temperature measurements from 60 km to a similar height are continuing.

In September/October a series of night-time SKUA soundings was made from Gan (Indian Ocean) to investigate the occurrence and features of gravity waves in the tropical atmosphere. On each of three occasions eight rockets were fired at intervals varying between ½ hour and 2 hours. Successful soundings of wind and temperature were made by 22 of the 24 rockets and provide a unique series of data which are being analysed.

Plans are in hand to take part, in the spring of 1973 at Thumba, India, in an internationally organized programme for the comparison of data produced by rocket-deployed sensors from different countries of origin over the altitude range of about 20–70 km.

In order to investigate a possible technique for the measurement of atmospheric ozone during darkness, lunar ultra-violet albedo observations were made from a SKYLARK rocket launched at Woomera, Australia, at the end of October. The flight was successful but the results remain to be analysed. An experiment to clear up certain anomalies in the behaviour of sensors used in earlier investigations to measure molecular oxygen in the thermosphere was also flown from Woomera.

In view of the need to re-allocate effort and the impossibility of obtaining a fully satisfactory description of the three-dimensional distribution of atmospheric ozone with currently available sondes, studies with balloon-borne sondes have been terminated following a series of soundings made with the stock of available sondes. Ground-based measurements of total ozone will continue.

Studies are being made of the large hemispheric changes of temperature which take place in the stratosphere during periods in winter known as stratospheric warmings. The atmosphere behaved very differently in the two winters 1970/71 and 1971/72 in this respect and measurements of temperature made by the Oxford–Reading University Selective Chopper Radiometer on the satellite NIMBUS D have been used to extend the analysis upward to the 1-mb level.

Results of wind observations to date in the 80–100-km height region

obtained by the use of the meteor-trail Doppler radar have been disappointing. Most of the assumptions originally thought to be satisfactory and appropriate to the reduction of the observations have proved to be of doubtful validity. A need to determine the position in space of the ionizing trails generated by meteors has been demonstrated and attempts are currently being made to modify and add to the equipment to make such measurements possible.

Work has continued on the laser equipment designed to measure dust and air density in the stratosphere from the energy scattered back from the laser beam to the ground. Adequate peak power is now being obtained from the equipment and the first observations are expected early in 1973.

The equipment for the large balloon experiments to measure water vapour in the stratosphere in conjunction with the National Physical Laboratory and the Atomic Weapons Research Establishment have been maintained in a state of readiness. However, no launches were made in 1972 owing to a combination of unfavourable meteorological conditions and flying restrictions arising from the need to keep clear of air lanes. The difficulties attendant on making such flights have led to a consideration of alternative methods of achieving the same objective and it is hoped to work in co-operation with the National Physical Laboratory on the development of such a method.

International co-operative satellite projects

Proposals for a revision of the terms of reference of the European Space Research Organization (ESRO) which were accepted by the participating governments envisaged a change of emphasis of the programme towards 'applications' satellites. As a consequence of this, proposals by ESRO, based on earlier work by the French Space Agency, for the launch in 1976 of a European meteorological satellite were discussed at length by the Directors of the European meteorological services and finally approved by the ESRO Council. This satellite, as at present planned, will provide from a geostationary orbit semi-continuous images of a large part of the continents of Europe and Africa from which cloud patterns and wind data will be derived. In addition the satellite may well have a role to play in the collection and distribution of data. The Meteorological Office has been closely concerned in the design and requirement studies, in the detailed definition of the meteorological uses of the basic data which can be obtained from this vehicle and in work undertaken internationally to specify the necessary ground station components of the overall system.

Following an invitation from the U.S. National Aeronautics and Space Administration, a visit was made to the U.S.A. to reach tentative agreement on proposals for U.K. participation in the programme for the next generation of American orbiting operational satellites provisionally known as the TIROS N series. Preliminary specifications and a draft memorandum of agreement were drawn up for the supply, by the U.K., of sounding instruments. Based on the successful Oxford–Reading University instruments flown on U.S.A. NIMBUS research satellites, they are intended to provide temperature data from the stratosphere to supplement tropospheric data provided by American instruments. Work has commenced on a design study to determine the best type of equipment, its main constructional features and the likely overall cost of participation in this programme. The outcome of this study is expected early in 1973.

Interpretation of satellite-borne radiometer measurements

A knowledge of the world-wide distribution of atmospheric temperature is one of the requirements for extended weather forecasting by numerical methods. Appropriate observations can be achieved on a world-wide basis by satellites through the measurement of the upward-directed radiation from atmospheric constituents in various spectral bands. The conversion of these radiances to temperature is carried out by what is known as the 'inversion' technique. Although well established in principle this technique requires substantial further development before it can be applied to yield the desired vertical profiles of temperature with the precision and regularity needed for operational application. A small group has been set up during 1972 to develop appropriate techniques for this work. Such activities are directly linked with U.K. participation in the TIROS N programme mentioned earlier.

Meteorological Research Flight

The Meteorological Research Flight is based at Farnborough, Hants, and is equipped with two aircraft, a Varsity and a Canberra. The Varsity aircraft is to be replaced by a C 130 Hercules aircraft and the replacement aircraft has been undergoing extensive modifications during the course of the year. Delivery to the Meteorological Research Flight is expected in mid 1973.

The Canberra aircraft is used primarily on investigations which require flights at levels in the upper troposphere and lower stratosphere. During the year a comprehensive data-recording system was received and the airborne equipment installed on the aircraft. The system comprises three parts. These are (a) the airborne data recording system (Plate X), (b) the ground replay equipment (Plate XI) and (c) the transcription and data-processing equipment (Plate XII).

The airborne system can record up to 24 channels of digital inputs and 24 channels of analogue inputs. The data are stored as 12-bit words on 1-inch-wide magnetic tape at a rate of 640 words per second. The aircraft control panel (left-hand side of Plate X) allows the observer to select any of the parameters which are being recorded for visual presentation. After the flight, the tape is played back through the ground replay system. A small computer rearranges the data into a format on $\frac{1}{2}$-inch magnetic tape suitable for input to a large computer. Some quality control and data reduction can be carried out at the same time.

During the course of its flying programme the Meteorological Research Flight has investigated regions of clear-air turbulence on a number of occasions in conjunction with the radar study based on the Defford radar and has carried out measurements of atmospheric pollution as indicated in preceding paragraphs. Flights have also been conducted to explore the air motion in and above the atmospheric waves which form in the lee of hills. Other projects have included the measurement of water vapour in the stratosphere and the development and proving of new instrumentation.

Geophysical fluid dynamics

Many of the fundamental dynamical processes which govern the behaviour of rotating fluids such as the earth's atmosphere or the oceans can be studied in the reproducible and controllable conditions of the laboratory. The use of laboratory systems to test theoretical ideas by experiment, in a way which is

not possible with the geophysical systems, is now a well-established method in geophysical fluid dynamics and one which the Meteorological Office has exploited for several years.

During the course of the year much attention was given to effects due to boundary layers and topographic irregularities at the base of the rotating fluid. Indications are obtained from this work as to the role which hills and mountains play in controlling the general circulation of the atmosphere.

In another series of experiments, a detailed examination of the spectra of disturbances in a rotating fluid has been made in regard to the spectra in both space and time. The spatial spectra of steady and vacillating flows invariably show that the dominant wave and its harmonics have the same phase speed. Other components have different phase speeds which are evidently simply related to that of the main wave. These processes are more complicated in the irregular régime, which provides a closer parallel with the atmosphere, and analysis of this régime is now being carried out. The three-dimensional structure of the velocity field for various thermally driven flows in a rotating annulus has been examined with a view to understanding some aspects of atmospheric structure. A technique of streak photography at seven levels in the fluid has been developed for the purpose.

Theoretical studies of rotating fluids have been extended to include hydromagnetic effects and it is now clear that there is a tendency towards a westward propagation of unstable waves arising from a non-uniform magnetic field and this persists even in a stratified fluid. This phenomenon may be related to the westward drift of the earth's geomagnetic field.

Dynamical and Synoptic Research

Research related to short-range weather forecasting

One of the principal tasks of meteorological services throughout the world is the provision on a routine basis of weather forecasts including winds and temperatures at levels from the surface to more than 10 km above it. Forecasts are issued for periods of a day or two ahead, thus providing meteorological guidance both for the general public and for more specialized purposes. For a long time effort has been devoted in the Meteorological Office as in other meteorological services towards improving these short-range forecasts. Over the last year attention has again been paid to providing more realistic detail in the forecasts and to extending the period over which useful advice can be given. The major effort has been concerned with those methods which are termed 'numerical weather prediction' in which the physical processes which dominate the development of the weather-bearing atmospheric systems are represented in mathematical form through the equations of motion and energy. In principle the complicated set of partial differential equations is sufficient to determine the developing patterns of wind, temperature and humidity in the atmosphere for at least a few days providing that these are well determined at the outset by the routine meteorological observations. The equations are highly non-linear and no useful exact solutions are known so that their solution must depend on the development of arithmetic methods of integration. More

than ten thousand million arithmetical operations are required in making a forecast for 24 hours ahead using the most recently developed forecasting scheme.

The main activity has been centred on the development of two versions of the 10-level model, which is described in some detail in the special topic on page 70. In brief the basic model predicts the developing fields of wind, temperature and humidity at 10 equally spaced pressure levels in the vertical, the highest being at about 16 km. It also predicts the rainfall reaching the ground. During the first half of the year there was considerable experimentation with both versions of the model; forecasts using each were computed daily in a semi-operational fashion and the results were examined by forecasting and research staff in collaboration. Throughout the period adjustments and innovations were made in order to improve their performance and on 1 August the octagonal-area coarse-mesh model which makes predictions for most of the northern hemisphere replaced the three-level model which had been used operationally since the mid sixties. The second version of the model, using a finer mesh, is designed for more-detailed predictions over an area centred on the British Isles and was thought to need further development and refinement before the forecasts based on it could be used on a routine basis by the Central Forecasting Office. These fine-mesh forecasts have been the subject of intensive study to improve the mathematical and physical formulations, especially as they affect the speed and amplitude of synoptic features, the development in the early stages of the forecasts and the adequacy of the analysis, especially of the humidity fields.

Many of the improvements that have been made were in the mathematical formulation of the arithmetical computations. In particular new techniques have been introduced in computing the terms which determine the speed with which weather systems move, in the representation of the effects of topography, and in the treatment of the motions near the edges of the areas. Much attention has also been paid to devising new integrational schemes which would reduce the amount of computation required to complete a forecast, and two of them are showing sufficient promise of economy to be under active experimentation. Studies have also been made of the mathematical representation of the physical processes and two new effects have been considered. The first involves representation of the ice phase in the precipitation process and has led to an indication in the computation of whether the precipitation is snow or rain. The second was the formulation of long-wave radiational cooling in the model; a number of trial forecasts have been produced, but further work will be required before this cooling effect can be included in routine forecasts. The procedure for analysis of observations taking into account earlier forecasts to form a suitable starting point for the numerical forecasts has been under constant revision. The analyses of humidity have received attention; a particular problem is to preserve the realistic tongues of high humidity which are developed in the forecasts by the model and which were smoothed by the previous analysis system. Reports from aircraft have been incorporated in the analyses relating to the upper air and the consistency between analyses for the surface and the upper air has been improved.

An interesting development now in its exploratory stage is the programming which will enable the computer to print out worded forecasts based on the 10-level model computations. The first of these were local forecasts for the Bracknell

area of wind, weather and maximum and minimum temperatures. However it is planned to attempt to extend the area and content.

A preliminary study is being made of the formulation of a model of the lowest 2 km of the atmosphere for inclusion in the prediction models such as the 10-level model. It is intended that this boundary-layer model will describe in some detail the exchange processes up to about 2 km and their interaction with the large-scale flow above, leading not only to a better prediction of the latter, but also to prediction of weather elements on a more local scale. The model is envisaged as having a very fine mesh in the horizontal, of about 10-km grid length, and several layers in the vertical. The ancillary mathematical work in the preparation of a viable computing scheme which will fit in well with the computations for the atmospheric development above 2 km is expected to be severe.

There are a number of forecasting problems which are local in the sense that the weather depends very much on nearby terrain, and these are best understood and solved by the forecasting staff at outstations. Advice on the way to attack these problems and access to the necessary data through use of the computer are provided by a small team at Headquarters. The scope of these investigations is wide, ranging from the use of observations obtained at several levels on tall television masts to the study of stratus cloud and fog in easterly winds and to obtaining predictions for snow. The Headquarters team also engages in research relevant to problems at outstations, such as the change of air temperature on passing over large tracts of water. Work on the empirical formulae used in forecasting visibility at London/Heathrow Airport has ceased since the change in amount of smoke in the air has rendered the old formulae obsolete. A search for new predictors has not yet been successful.

Research related to long-range forecasting

The preparation of weather forecasts for a month ahead has continued. They are prepared at the beginning and the middle of each month and are made available to the public through the Press, radio and television. The detailed forecast along with statistics of the weather of the month in question are made available at a small charge to subscribers, who number more than 2000. There is no known basis for predicting the weather over 30 days in the same detail as for a few days ahead and the forecasts are not intended to be applied to any individual day. The U.K. is divided into 10 areas and for each of these the forecast gives the expected mean monthly temperature anomaly in one of five categories (equally likely over a long period of years) and the expected mean monthly rainfall anomaly in one of three. The broad march of the monthly weather is also forecast with particular emphasis on the first week or so. The success of the forecasts was greater than in 1971, although summer forecasts once again proved the most difficult. The summer of 1971 was very unusual, and so was the summer of 1972. The first half of the 5-month period from May to September, up to mid July, was cold, wet and cyclonic with almost the coldest June in the last hundred years; the second half, to the end of September, was exceptionally dry and anticyclonic, though it continued cool. Such a sharp change in mid-July is unprecedented and it is not surprising that forecasts based largely on analogue methods should show some failures over the summer period. The abnormal conditions of early summer seem to be attributable to ocean temperature anomalies resulting from excessive

movement southward of pack ice in the Labrador current. Studies of cases such as this bring to light factors which contribute towards variations of weather in the United Kingdom.

The ability to carry out research in long-range forecasting depends to a great extent upon being able to process and examine large quantities of data, and over the past decade a very large bank of data has been assembled in a form readily available for use in a computer. Programs for processing the data have also been built up. It seems likely that the data bank now contains nearly all the meteorological data over the last 100 years which are likely to be useful in long-range forecasting. The bank has been enlarged during the year, notably in regard to derived data. For example, a complete catalogue of daily weather types for the area 50°–60° N, 60°–70° W, including Labrador, from 1880 to date has been made available and analogue selection based on this catalogue has been added to the other methods in routine use in the preparation of the monthly forecast. Again, mid-month to mid-month mean temperature anomalies for central England from 1870 to date have been estimated, and this has allowed the development of rules for forecasting for mid month to mid month, similar to those for monthly forecasting.

Research has also been actively pursued into the relation between anomalies of sea surface temperature and the future behaviour of the atmosphere especially as regards the weather over the United Kingdom. It has been shown that in winter the anomaly of temperature in an area in the north central Pacific Ocean has a correlation with the weather over U.K. a month later. Using the previous similar work concerning sea surface temperature anomalies over the Atlantic Ocean, it is now possible occasionally to consider the combined effect of the two oceans on the general circulation a month ahead. An investigation using sea temperatures at Puerto Chicama, Peru, shown by several recent studies to be associated with the atmospheric circulation over North America and the Pacific Ocean, indicated that they appear to have little or no predictive use for the United Kingdom.

Experimental seasonal forecasts have been produced for each of the four seasons as tests of the methods of forecasting which are being evolved. An encouraging level of success has been maintained. There have been requests for weather advice on a seasonal time-scale from industrial and other concerns, indicating the potential value of this research.

The examination of great quantities of data, necessary both in the research work and in preparing the forecasts requires organization if the computer is to be used effectively to do the task. The special Meteorological Office computer language has been almost completely rewritten to operate on the IBM 360/195. A computerized system for the cataloguing and retrieval of meteorological data has been developed under the auspices of the World Meteorological Organization, and will appear as one of their documents; the system is now in use in the Office in cataloguing information relevant to long-range forecasting.

Climatic change

Interest in the study of climatic change again increased both at national and international level and was manifest in the United Nations Conference on the Human Environment which stimulated much discussion at official level and in scientific journals and the mass media. It is important to establish the natural variations that have occurred in the past when there was little possibility

of man-made effects. In earlier years the Meteorological Office programme of research on climatic change has been under the direction of Mr H. H. Lamb. At the beginning of 1972 Mr Lamb left the Office to take up a professorial post at the University of East Anglia where he has established a Climatic Research Unit to pursue studies along similar lines. Following Mr Lamb's departure the Meteorological Office programme is being re-established with particular emphasis on examining the evidence for climatic swings over periods of a century or two.

General circulation of the atmosphere

One of the central problems of meteorology is the explanation of the general circulation of the atmosphere and the estimation of the effects of alterations to the earth–atmosphere system. The importance is two-fold; first there is the possibility of considerably extending the period over which useful weather forecasts can be made and determining the limits of predictability. The second arises from the possibility that mankind may in the future alter the world climate, either inadvertently or by design. The world-wide process of industrialization is growing so rapidly that there is some concern as to whether ultimately the climate may be appreciably altered by changes in land use and by pollution of the atmosphere and the ocean. It is essential to have a thorough understanding of the reaction of the atmosphere to such changes if the effects are to be assessed before the event. The development of models leading to this understanding has been one of the prime research tasks of recent years, but even yet the models do not warrant high confidence in their predictions.

The most promising method of attacking these problems is the construction of mathematical models similar to those used in numerical weather forecasting for a few days ahead but specially designed to allow calculations covering long periods without accumulating systematic errors. The installation of the new computer in the Meteorological Office has allowed this work to proceed at a much faster pace than hitherto and the model developed over the last few years (its plan was described in the special topic 'The general circulation of the atmosphere' in *Annual Report on the Meteorological Office,* 1967) has been extensively used in experimentation. The analysis of the numerical simulation of the general circulation of the atmosphere during the northern hemisphere winter was completed and a substantial paper has been published with another to follow. An attempt was made to simulate the northern hemisphere summer circulation by integrating the model forward in time for 80 simulated days with all the parameters, such as solar elevation and sea surface temperature, set to their July values. Although some of the mean patterns are quite realistic there was a substantial deficiency in the energy associated with cyclonic motions and a tendency for sea-level pressures to be too low over the continents and too high over the seas and polar regions. This latter tendency has been a feature of the model predictions and some improvement has been made by reducing the assumed thermal capacity of arctic sea ice and by introducing an upward heat flux through the ice. This results in a warmer lower atmosphere and a fall in surface pressure in polar regions.

A number of experiments have been conducted to examine the effects on the model integrations of imposing various sea surface temperature anomalies. Such anomalies once established often last for months and research into long-range weather forecasting has shown that they are well correlated with

anomalies of surface pressure and temperature in succeeding months. The experimental results were generally in agreement with theoretical calculations made elsewhere, but rather less well with what is observed to occur in the real atmosphere.

The results of an experiment modelling the northern hemisphere winter but with the ice of the Arctic Ocean replaced by water at freezing temperature were rather unexpected in that, along with the expected rise of temperature in arctic regions, the mid-latitude continental temperatures fell appreciably in the east; the results reinforce the view that qualitative argument applied to such problems is unreliable.

A number of physical aspects of the model have been altered and the new formulations tested and accepted where they led to improvement. Examples are the reduction of the flux of sensible heat to the model atmosphere from the underlying surface and the modification of the scheme for the simulation of free convection on the sub-grid scale. The model has also been extended to simulate global circulations, in order to remove the constraint of an artificial boundary at the equator and allow cross-equatorial flow including monsoonal effects; the model performance in mid latitudes should also be enhanced. Opportunity was taken during this work to make the programs more efficient, so that the global model forecasts require only 20 per cent more computer time than those for the corresponding hemispheric model. Advantage will be taken of this economy to add two more levels, one in the stratosphere and one in the boundary layer. A new higher-resolution global model with about 10 000 grid points at each of 11 layers is being developed and should be working early next year; the additional resolution will allow better representation of the physical processes. These further developments should put the Office in a good position to take advantage of the greatly increased number of meteorological observations during the First Global Experiment to be conducted in the international Global Atmospheric Research Programme (GARP), at present scheduled for 1977, as well as to play a major part in the research associated with the international Atlantic Tropical Experiment (GATE) to be carried out in 1974.

A great deal of the associated research has had a strong mathematical flavour, calling for an up-to-date knowledge of techniques of solving mathematical problems using computers. In particular a number of experiments aimed at optimizing the time and space smoothing within the model have led to methods of solution with less horizontal diffusion and consequently better representation of the baroclinic motions which are so important in transferring energy polewards and in determining extratropical weather. Progress has been made in the use of finite-element methods in the solution of equations similar to those which occur in the mathematical formulation of the model and a general study of the methods of handling these equations has been initiated. Useful advances have also been made in the problem of initialization, i.e. obtaining at the grid points values of the meteorological elements which are balanced so that the subsequent development of the meteorological motions is not masked by spurious motions of other types. A procedure which is computationally economic has been developed for carrying out this balancing process in which the subtle adjustments between wind and pressure fields are made by the predictive equations themselves. Experimental work on the use of grids having variable resolution in space has continued and successful integrations

using such grids have been achieved in simple cases. If the work can be extended for use in the full models it will open the way to carrying out detailed examination of limited areas without requiring high resolution over the whole sphere.

Models of the general circulation must take account of the radiative processes of the earth–atmosphere system, and the current scheme developed in conjunction with the Clarendon Laboratory, Oxford, is based on the use of empirical emissivities. A review of the whole question of the treatment of radiation has been initiated with a view to devising improved numerical representations in the models. Some preliminary work has been done on the possibility of simulating mathematically the behaviour of the upper layers of the ocean, with a view to coupling such a model with atmospheric models and so removing the constraint imposed by using fixed sea surface temperatures.

The Atlantic Tropical Experiment will take place in 1974 and the International Scientific Management Group (ISMG) associated with it is situated in Bracknell and co-operating freely with the Office. In order to ensure that maximum benefit from GATE and the proximity of ISMG the nucleus has been set up of a subgroup charged with developing mathematical models of atmospheric motions in the tropics for later introduction into the global models. It is expected that this group will be strengthened early next year and that it will play a leading role in the interpretation and use of the great numbers of data of different kinds which will be observed during GATE.

The diagnostic studies of tropical motions have continued with attention paid to the spatial coherence of tropical winds, the equatorial motions at about 16 km and the relation between tropospheric winds and the occurrence of rainfall near the equator.

Early in the year the development of an 8-level model of the upper atmosphere above 100 mb was continued, the reprogramming for the new computer making experimentation easier, but some of the problems associated with unexplained wave-like motions remain to be solved.

Some doubts have been expressed about the wisdom of flying aircraft in the lower stratosphere lest the product of combustion should significantly alter the constitution of the atmosphere at these levels, and lead to a deterioration in the human environment. A Committee on Meteorological Effects of Stratospheric Aircraft (COMESA) has been set up to direct and co-ordinate a programme of research, expected to last for three years, aimed at determining the natural composition of the stratosphere along with the natural variations. The Committee aims to assess the changes that might arise from the operation of aircraft. Its programme is directed to the meteorological effects, if any, consequent on these changes. The Committee, which first met in July 1972, now directs a programme of research into the basic photochemical reactions which determine the composition of the atmosphere, the distribution of minor atmospheric constituents within the stratosphere and modelling of the atmospheric structure and dynamics. Part of the work has been contracted out, university groups at Oxford and Cambridge investigating chemical reaction rates and groups at Oxford University and the National Physical Laboratory being engaged in devising the measurements of ozone, humidity, oxides of nitrogen and other stratospheric constituents.

A mathematical treatment is being developed of the detailed photochemistry as radiation traverses a vertical air column. The problem of the interrelation

between the atmospheric motions and the photochemical effects is being examined by a model representing variations of both with height and latitude and preliminary work is in progress towards constructing a full three-dimensional model in which the physics and chemistry are adequately represented. Research into the effects of flying aircraft in the lower stratosphere is being pursued also in the U.S.A., mainly through their Climatic Impact Assessment Program, and in France, and there is considerable interchange of information and international co-operation in this work.

Charts and diagrams describing the climatology of the 30-mb level (about 24 km) in the northern hemisphere in February, March and April have been published and work on a similar publication for August, September and October is continuing.

Special investigations

Many of the requests for meteorological advice cannot be met directly from the main streams of meteorological research or from a brief examination of data. Often the advice is needed urgently and special investigations are needed to fulfil the requirement.

Problems studied in relation to the development of the Concorde aircraft have included the origin of sudden changes observed in the ambient temperature, the occurrence of large wind shears and the meteorological instrumentation of the aircraft for investigational purposes. Further intensive studies have been made of the occurrence of clear-air turbulence, and during the spring a joint investigation was carried out with the Royal Aircraft Establishment in which special observations were made during selected periods by the Meteorological Research Unit, the Meteorological Research Flight and Royal Aircraft Establishment aircraft; at the same time reports were organized from air pilots, both civil and service, of the occurrence in their routine flights of clear-air turbulence. The results are being studied, and the efficiencies of various indices of the existence of clear-air turbulence are being tested with a view to developing forecasting methods.

Studies relating to storms over north-east India have been completed and a climatology of giant cumulonimbus clouds is being prepared. Further studies have been made of the photographs of radar cloud eddies observed at Singapore and Gan and have produced statistics of the occurrence of tropical storm clouds and probabilities of aircraft encountering them.

Work on the revision of the *Handbook of Weather Forecasting* has continued.

Other inquiries have concerned air pollution, with development of a computer program to predict the visible length of incinerator plumes, radio propagation and its attenuation due to high-intensity rainfall, poor visibility or strong wind shears in relation to aircraft operation, climatological extremes and their probabilities, and the preparation of meteorological appreciations for various areas and air routes.

General Activities of the Research Directorate

The Meteorological Office continued to maintain close contact with the Natural Environmental Research Council and the Royal Society in regard to meteorological research. Several members of the Meteorological Office staff serve on

relevant committees of these bodies. Five small research projects in the universities are directly supported by grants from the Meteorological Office and nine others are supported by the Gassiot Committee of the Royal Society with funds provided by the Office. Seven members of the university staffs worked in the Office as consultants for short periods during the year. Ten research scientists from overseas carried out research in the Meteorological Office for extended periods during 1972, being supported by their home institutions or by international fellowships.

Meteorological Office scientists continue to play an active part in the international development of meteorology by their membership of the international committees set up by the International Association of Meteorology and Atmospheric Physics, by their participation in the activities of the commissions and working groups of the World Meteorological Organization and by their involvement in the planning of the Global Atmospheric Research Programme—a joint project of the World Meteorological Organization and the International Council of Scientific Unions.

During August an International Cloud Physics Conference was held in London and Meteorological Office scientists took an active part in both its organization and its proceedings. Following this conference the Office acted as host to a small working group of the WMO which considered questions of cloud physics and weather modification. This met at the Meteorological Office College at Shinfield Park, near Reading.

The scientific research of the Office was reviewed by the Meteorological Research Committee and its subcommittees during the course of nine meetings. During the year a comprehensive system was introduced for the purpose of assessing the costs of research projects. This will form the basis for the planning and review of research expenditure in future years.

Library, Publications and Archives

The National Meteorological Library forms part of the Meteorological Office Headquarters at Bracknell. It is used mainly by staff of the Office but it is also accessible to the professional user from outside the Office and to members of the general public. Almost one-third of the loans of publications were to borrowers in these last two categories.

The library provides a comprehensive coverage of the literature of meteorology and associated subjects. An indication of the activities of the year is contained in Table XVI on page 94. The number of items classified and catalogued (8938) was the highest on record, being over 20 per cent greater than that of last year. The very high rate of borrowing (18 291 items) was maintained.

During the second half of the year a start was made on an investigation by the Systems Development Branch (Met O 22) into library systems with a view, in the first instance, to the possible introduction of fully automated cataloguing procedures.

Students from library schools have continued to visit the library in groups, or as individuals, in the course of their practical work. Library staff of the Office have continued to participate in the facilities offered by the Association of Special Libraries and Information Bureaux (ASLIB) and the Circle of State Librarians.

Meteorological observations in manuscript and other original documents of the Meteorological Office are kept, in accordance with the Public Records Act of 1958, in special repositories (Archives) in Bracknell, Edinburgh and Belfast. At Bracknell loans to Office staff have shown an increase of 27 per cent on 1971, and visitors from outside the Office have numbered in excess of 200.

Several meetings of a Working Group on Archives were held during the year to revise instructions for the retention period of technical records, and to make recommendations for retention periods of various machine-readable data banks (on magnetic tape).

The Editing Section is responsible for the preparation for printing of most of the serial and occasional publications sponsored by the Office. Those issued during 1972 are listed in Appendix III. The Section works in close co-operation with Her Majesty's Stationery Office and ensures that the publications which it edits conform with laid-down rules and standards and with the precepts of the British Standards Institution. The publications edited include *Geophysical Memoirs*, *Scientific Papers*, and the *Meteorological Magazine*. This magazine is published monthly and provides a valuable medium for the dissemination of short papers dealing with theoretical and practical research work and instrument development.

The Cartographic Drawing Office prepares diagrams for Meteorological Office publications, for internal memoranda and for reports in scientific journals of research by Meteorological Office staff. It also prepares for various areas of the world the many charts and diagrams which are used as background maps on which meteorological observations are plotted.

Training

As a result of a review of the training responsibilities in the Meteorological Office, and of the increasing importance of both professional and management training, it was decided that the organization for training should be changed. The responsibilities in respect of professional training exercised in the past by the Assistant Director Meteorological Office (Publications and Training) were transferred in April to the Principal of the Meteorological Office College. The responsibilities for arrangement of management training and the planning of training for the individual as an integral part of career management were transferred to the Staff Branch, Met O 10, in care of a Senior Principal Scientific Officer who reports to the Secretary of the Meteorological Office. In consequence, the post of Assistant Director Meteorological Office (Publications and Training) has been abolished, and the Principal of the College has assumed the additional title Assistant Director Meteorological Office (Professional Training).

Training policy is now determined and kept under review by a Training Board comprising the Director-General, the Directors of Services and Research, and the Secretary of the Meteorological Office with the Principal of the College as Secretary. The first meeting of the Board was held in August. It has set out to examine the implications for professional training of the quickening pace at which the science of meteorology is developing, of the unification of the three scientific classes, and of the rising level of qualification of those entering the

Office in the Assistant Scientific Officer, Scientific Officer and Higher Scientific Officer grades. The Board also began to look at management training needs and the ways in which these can best be fulfilled.

The pattern of external training set largely in past years by the need for members of the Scientific Assistant grades to study 'A' levels in mathematics and physics and related subjects to qualify for class-to-class promotion, responded quickly to changes in Civil Service regulations introduced with the new class structure. The Higher National Certificate (H.N.C.) has been set as the minimum academic standard for entry by Open Competition to the new Scientific Officer grade, which embraces the former Senior Scientific Assistant, Assistant Experimental Officer and Scientific Officer grades. In consequence the attainment of appropriate 'A' levels has become, for many Assistant Scientific Officers, a step in the direction of an H.N.C. in mathematics, statistics and computing, in applied physics, or in pure mathematics or computer science. H.N.C. courses are less widely available at Technical Colleges and Colleges of Further Education than are those for 'A' levels. Consideration is being given to the feasibility of establishing a block release scheme for staff employed at offices which are not within reasonable travelling distance of colleges offering suitable day classes.

The majority of external trainees take advantage of the provisions for day release to attend classes on a part-time basis. A small number, limited at any one time to 12, are able to obtain full-time release for university studies. A new avenue which has opened up for such students is the Sandwich Course, organized jointly by the Department of Geophysics at the University of Reading and the Meteorological Office. This course leads to an honours degree in meteorology in about three and a half years. It follows the usual pattern for Sandwich Courses in that periods of study at the University alternate with 'industrial' periods spent within the Meteorological Office.

The more important features of the new Meteorological Office College at Shinfield Park near Reading were described in the *Annual Report* for 1971. Use of the tutorial and residential facilities has been growing as planned. The prime function of the College is as a Training Centre for Meteorological Office staff and their overseas colleagues. However, its capacity to serve, as the incidence of courses permits, as a venue for scientific meetings is becoming increasingly appreciated and it has been used in recent months for three- or four-day meetings of international meteorological working groups and panels. It will be host in May 1973 to a Symposium on fine-mesh modelling in numerical weather prediction organized jointly by the World Meteorological Organization and the International Council of Scientific Unions.

The standard courses held at the College underwent little structural change during the year, although the trend for strengthening in the areas of radar meteorology, satellite meteorology, numerical weather prediction, computer appreciation and meteorological statistics continued. The series of courses caters for staff at successive stages of their professional careers. Their academic standards range from 'O' level to the level of postgraduate mathematics and physics. The College calendar and details of courses held both at the College and at the Radiosonde Training Centre at Hemsby, Norfolk, including syllabuses, are contained in *Meteorological Office Leaflet No.* 4, which is published annually and which is available on request from the Principal, Meteorological Office College, Shinfield Park, Reading RG2 9AU.

Management training for Meteorological Office staff is provided mainly by the Management Studies Centre of the Ministry of Defence and by the Civil Service College but several professional courses at the Meteorological Office College now include an element of management training. Selected senior staff attend courses at the National Defence College or at other centres providing management training. In 1972, 77 officers received training in management apart from that included in professional courses at the Meteorological Office College.

The six-months' course in the installation and maintenance of electronics instruments used in Meteorological Offices at home and abroad was again held at Beaufort Park. In preparation for the Beaufort Park course five new-entrant trainees received instruction in basic electronics at RAF Sealand. Regular courses in radiosonde operation were attended at the Meteorological Office at Hemsby, by staff from Britain and overseas.

Further details of courses completed in 1972 at the three Meteorological Office Training Establishments are contained in Table XVII. Participation of students from overseas countries continued at a high level. Two overseas students on Meteorological Office courses and 12 overseas students taking degree courses at the University of Reading were sponsored by the Meteorological Office under the Voluntary Aid Programme of the World Meteorological Organization. Of the 12, two completed M.Sc. courses and five were awarded B.Sc. in physics with meteorology. Seven new awards were made in 1972, of which two were for the new Sandwich Course. The Sandwich Course is particularly attractive for those members of overseas services wishing to return to their countries with both a degree in meteorology and professional training in the practical aspects of weather forecasting.

Members of the staff released for part-time study during the year at Technical Colleges and Colleges of Further Education numbered 316. Other members of the staff received assistance under the further education scheme, 19 availing themselves of the facilities of the Open University.

J. S. SAWYER
Director of Research

STATISTICS OF THE RESEARCH DIRECTORATE

TABLE XVI—LIBRARY AND ARCHIVES

Library

Items received, including duplicates but excluding daily weather reports	8 032
Individual books, pamphlets, articles and microfilms classified and catalogued	8 938
Transparencies acquired	175
Publications lent (excluding daily weather reports and internal 48-hour loans)	18 291
New agreements for exchange of publications	1
Total number of exchange agreements	375
Number of pages translated by Library translators	
Russian	1 614
German	227
French	30
Hungarian	18
Italian	8
Dutch	7
Number of pages translated by freelance translators	472
Total	2 376

Archives

Number of loans	2 664

TABLE XVII—TRAINING

The following figures give details of courses completed during 1972 at the Meteorological Office training establishments at Shinfield Park, Hemsby and Beaufort Park.

	Number of courses	Length of course in weeks	Number of students
Scientific Officers	1	28	13
Initial Forecasting	2	15	26
Advanced Forecasting	4	6 (7*)	27
Extension Course	2	4	23
Senior Meteorologists	1	3	24
Basic Meteorology—Forecasters	2	4	29
Meteorological Statistics	1	4	7
Tropical Meteorology	2	3	19
Mediterranean Meteorology	2	3	7
Advanced Instruments	3	2	24
Auxiliary and Voluntary Observers	6	1	63
Basic Meteorology—Assistants	2	4	16
Initial Assistants	8	4	75
Advanced Assistants	6	6	52
Tropical Synoptic Assistants	1	8	7
Radiosonde (Initial)	4	9	10
Radiosonde (Refresher)	2	5	2
Radiosonde (Advanced)	3	4	6
Radiosonde (British Antarctic Survey Special)	1	4	4
Radiosonde (GRAW-sonde Special)	3	2	3
Electronics	1	22	12
Total			449

*as from AF1/72

Students from the following territories attended courses which terminated during 1972.

	Number of students
Afghanistan	3
Antigua	1
Bahrain	2
Belgium	1
British Honduras	1
Burma	1
Channel Isles	1
Cyprus	2
East Africa	5
Ethiopia	3
Hong Kong	1
Jordan	5
Kuwait	2
Libya	2
Malaysia	3
Malta	3
Mauritius	1
Netherlands	5
Seychelles	7
Singapore	2
Switzerland	5
Thailand	1
West Indies	3
Total	60

INTERNATIONAL CO-OPERATION

The 24th Session of the WMO* Executive Committee was held in Geneva from 22 to 31 May. The Director-General, Dr B J Mason, was accompanied by Mr D. Hanson, Secretary, Meteorological Office and Mr D. G. Harley, Assistant Director (International and Planning). Mr J. S. Sawyer, Director of Research, attended as President of the Commission for Atmospheric Sciences. The Preparatory Working Committee, attended by Mr D. G. Harley, met from 15 to 19 May to deal with the more routine matters. The main problem was WMO's financial crisis caused by the devaluation of the United States dollar. Some economies were made, mainly in the costs of meetings. Other important topics included the tropical storm project, modification of weather and climate, hydrology, aeronautical meteorology and a decision that WMO should aim to take over from ICAO the North Atlantic Weather Ships.

An extraordinary session of WMO's Regional Association VI (Europe) was held in Lucerne from 19 to 26 April. It was attended by Mr P. J. Meade, Director of Services, Mr J. K. Bannon, Deputy Director (Observational Services), Mr T. H. Kirk (Chief Forecasting Adviser) and also by Instructor Captain J. A. Bell (Meteorology and Oceanographic Services (Naval)). The work of the session was mainly directed to improving regional co-operation in meteorology.

Two Technical Commissions of WMO met during the year. The Commission for Hydrology met from 3 to 17 April in Buenos Aires. The U.K. delegation was led by Mr J. Harding, Assistant Director (Agriculture and Hydrometeorology) and included Mr A. Bleasdale (Met O 8), Mr H. J. Richards (Water Resources Board) and Mr K. A. Edwards (Institute of Hydrology). The Commission paid particular attention to the strengthening of WMO's programme in operational hydrology and the Organization's role in a long-term programme of international co-operation in hydrology following the end of the Unesco-sponsored International Hydrological Decade in 1974. The Commission for Marine Meteorology met in Tokyo from 9 to 21 October. Mr J. K. Bannon, Deputy Director (Observational Services) led the U.K. delegation which also included Captain G. A. White (Marine Superintendent) and Captain R. R. Fotheringham, Director of Meteorology and Oceanographic Services (Naval). The Commission was particularly concerned with meteorological services supporting marine activities and with the problems of monitoring the marine environment. Immediately before the session of CMM, WMO sponsored in Tokyo a Technical Conference on the Means of Acquisition and Communication of Ocean Data. It was attended by Mr M. J. Blackwell, Assistant Director (Operational Instrumentation), Captain G. A. White, Captain R. R. Fotheringham and five other representatives from elsewhere in the United Kingdom. Mr M. J. Blackwell also attended the simultaneously held Second International Ocean Development Conference.

Mr P. J. Meade, Director of Services, Mr V. R. Coles, Deputy Director (Forecasting Services) and Captain G. A. White (Marine Superintendent) attended the seventh ICAO Conference on Joint Financing of the North Atlantic Ocean Stations in Paris from 7 to 23 March 1972. Agreement was

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* A list of abbreviations used in this section, and their meanings, is given on page 103.

reached on the continuation and financing of the ocean weather ship network until 30 June 1975, when a new agreement under WMO may be brought into operation.

Discussions continued throughout the year on the meteorological COST projects (European co-operation in science and technology). Mr P. J. Meade made six visits to Brussels and Mr D. G. Harley four visits, on the biggest project, that for a European Centre for Medium-range Weather Forecasts. Mr M. J. Blackwell attended in June a session of the working party on meteorology and oceanography, and Mr G. A. Clift (Met O 16) attended three meetings and Mr G J Day (Met O 16) one meeting of a study group on the development and standardization of meteorological instruments.

Other WMO meetings, or joint WMO meetings with other international bodies, in which Meteorological Office staff took part, were as follows:

Subject	*Place and date*	*Attended by*
Informal Planning Meeting on NAOS	Geneva February	Mr P. J. Meade, Director of Services
RA VI Working Group on Meteorological Telecommunications—10th Session	Paris February	Mr E. J. Bell, Assistant Director (Telecommunications) Mr R. K. Pilsbury (Met O 5)
GARP Research Co-ordination and Planning Group No. 5	Leningrad March	Mr F. H. Bushby, Assistant Director (Forecasting Research)
GARP Study Group on The Parameterization of Sub-grid-scale Processes	Leningrad March	Dr P. W. White (Met O 11)
WMO/IOC Group of Experts on IGOSS Technical Systems	Geneva March	Mr G. J. Day (Met O 16)
RA VI Working Group on Radiation	Beirut March	Mr R. H. Collingbourne (Met O 1)
Polar Panel of CMM Working Group on Marine Climatology	Geneva April	Mr H. C. Shellard (Met O 3)
Tropical Experiment Board—3rd Session	Geneva April	Dr B. J. Mason, Director-General Mr R. F. Jones, Deputy Director (Physical Research)
Executive Committee Panel of Experts on Voluntary Assistance Programme	Geneva May	Dr B. J. Mason, Director-General
WMO/IUGG Symposium on Radiation	Sendai, Japan May	Dr K. H. Stewart (Met O 19)
WMO Working Group on Statistical Methods and the use of Mathematical Models in Climatology and Special Applications of Meteorology	Brussels May	Mr J. M. Craddock (Met O 13)
CBS Working Group on Global Telecommunication System Study Group on Message Procedures and Routeing—1st Session	Geneva May	Mr E. J. Bell, Assistant Director (Telecommunications)
Joint Organizing Committee for the Global Atmospheric Research Programme—7th Session	Munich June–July	Mr J. S. Sawyer, Director of Research
Joint IOC/WMO/FAO *ad hoc* Task Team for the Determination of User Applications of Ocean Analysis and Prediction Services	Paris June	Captain G. A. White (Marine Superintendent)

Subject	*Place and date*	*Attended by*
WMO/IASH Symposium on Distribution of Precipitation in Mountainous Areas	Geilo, Norway July–August	Mr A. Bleasdale (Met O 8) Dr T. W. Harrold (Met O 8) Mrs P. M. Salter (Met O 8)
International Cloud Physics Conference —10th Session	London August	Dr B. J. Mason, Director-General Mr J. S. Sawyer, Director of Research (Chairman) Dr D. G. James (MRF) Mr D. N. Axford (MRF) Mr S. G. Cornford (Met O 9) Dr D. A. Johnson (Met O 15) Dr G. E. Hunt (Met O 20)
CAS Working Group on Cloud Physics and Weather Modification	Shinfield Park, Reading August	Mr P. Goldsmith, Assistant Director (Cloud Physics) Dr J. L. Brownscombe (Met O 15)
WMO Co-ordination Team on Implementation of Global Telecommunication System in Africa	Lagos and Kano August	Mr C. E. Goodison (Met O 5)
Planning Conference on First GARP Global Experiment (FGGE)	Geneva September	Dr B. J. Mason, Director-General Mr M. H. Freeman, Deputy Director (Communications and Computers)
Tropical Experiment Council—2nd Session	Geneva September	Mr M. H. Freeman, Deputy Director (Communications and Computers) Dr N. E. Rider, Assistant Director (High Atmosphere)
CIMO Trials of Reference Radiosondes	Shinfield Park, Reading September	Mr A. H. Hooper (Met O 16)
WMO/IOC Group of Experts on IGOSS Technical Systems—Discussion of Co-rapporteurs	Bergen September	Mr G. J. Day (Met O 16)
Meeting on Implementation of Segments of Main Trunk Circuit Washington/Bracknell/Paris/Offenbach	Washington September	Mr E. J. Bell, Assistant Director (Telecommunications) Mr R. Ross (Met O 5)
CBS Study Group on the Guide to the Global Data Processing System (GDPS)	Geneva October	Mr T. H. Kirk (Met O 2)
Bilateral Meeting U.K./France on Digitized Facsimile Transmissions	Paris October	Mr C. E. Goodison (Met O 5)
CIMO Working Group on Radiosonde Instruments and Measurements	Shinfield Park, Reading October	Mr A. H. Hooper (Met O 16)
WMO Commission for Atmospheric Sciences Advisory Working Group—1st Session	Geneva November	Mr J. S. Sawyer, Director of Research (Chairman)
CIMO Working Group on Measurements of Evaporation and Soil Moisture	Geneva November	Mr R. H. Collingbourne (Met O 1)
Joint Support U.K./Iceland/WMO Mission to Iceland on Analysis and Planning of Future Meteorological Telecommunication System	Reykjavik November	Mr J. D. Lunn (Met O 5)
CBS Working Group on Global Telecommunication System Study Group on Message Procedure and Routeing —2nd Session	Geneva November–December	Mr P. Horsley (Met O 5)

Subject	*Place and date*	*Attended by*
CBS Working Group on Codes	Geneva December	Mr N. E. Davis (MetO 13)
CBS Informal Planning Meeting on Date of Introduction of New SYNOP and SHIP Codes	Geneva December	Mr M. H. Freeman, Deputy Director (Communications and Computers)
RA VI Working Group on Meteorological Telecommunication Study Group on Rerouteing of Messages and Continuity of Service	Geneva December	Mr P. Horsley (MetO 5)
RA VI Working Group on Meteorological Telecommunication Study Group on Transmission Programmes, Main Trunk Circuit	Moscow December	Mr D. McNaughton (MetO 5)
CBS Working Group on Global Telecommunication System Study Group on Digitized Facsimile Transmissions	Geneva December	Mr C. E. Goodison (MetO 5)
Co-ordination with WMO for METEOSAT	Geneva December	Mr D. G. Harley, Assistant Director (International and Planning)
Co-ordination Meeting of Experts on the Implementation of the EMTN	Geneva December	Mr E. J. Bell, Assistant Director (Telecommunications)

Attendances, not already listed, at international conferences sponsored wholly or primarily by bodies other than WMO, and other visits abroad were as follows:

Subject	*Place and Date*	*Attended by*
ESRO GFGMS Sub-Group on Meteorological Data Processing Methods	Washington January	Mr D. E. Miller (MetO 19)
NATO Sub-Group Meetings of Military Committee Meteorological Group Working Group on Weather Plans	Norfolk, Virginia January	Mr D. W. Tann (MetO 6)
NATO MCMG Study Group Meeting on Special Telecommunication Problems	Brussels January	Mr E. J. Bell, Assistant Director (Telecommunications)
NATO Sub-Group Meeting of MCMG Working Group on Weather Plans	Brussels February	Mr D. W. Tann (MetO 6)
Climatic Impact Assessment Program Meeting	Boston, Mass. February	Dr R. J. Murgatroyd (MetO 20)
ESRO *ad hoc* Group on Space Meteorology	Rome February	Dr K. H. Stewart (MetO 19) Mr D. E. Miller (MetO 19)
ESRO Working Group on Ground Facilities for a Geostationary Satellite (GFGMS)	Paris February, April, July, October, November, December	Mr D. E. Miller (MetO 19)
ESRO GFGMS Sub-Group on Meteorological Data Processing Methods	Paris February, March and September	Mr D E. Miller (MetO 19)
Inter-Governmental Maritime Consultative Organization Sub-committee on Safety of Fishing Vessels—12th Session	London February	Mr H. C. Shellard (MetO 3) (WMO representative)
Planning new upper-air and surface observing stations in Seychelles	Seychelles and Nairobi February–March	Mr G. Needham (MetO 17) Mr M. E. Robson (MetO 1)
Inspection of surface station and planning new upper-air station	St Helena February–March	Mr W. J. Bruce (MetO 17)

Subject	*Place and date*	*Attended by*
NATO MCMG Working Group on Weather Plans and Weather Communications	Athens March	Mr E. J. Bell, Assistant Director (Telecommunications) Mr D. W. Tann (MetO 6)
Division of Planetary Sciences, American Astronomical Society	Hawaii March	Dr G. E. Hunt (MetO 20)
Conference on The Core-Mantle Interface	Melbourne, Florida March	Dr R. Hide (Head of MetO 21) Dr D. Acheson (MetO 21)
Conference on High-pressure Physics and Planetary Interiors	Houston, Texas March	Dr R. Hide (Head of MetO 21)
IMCO Maritime Safety Committee—25th Session	London March	Captain A. D. White (MetO 1)
ESRO *ad hoc* Group on Space Meteorology	Offenbach March	Dr K. H. Stewart (MetO 19) Mr D. E. Miller (MetO 19)
ESRO *ad hoc* Group on Space Meteorology, Sub-Group on the METEOSAT Ground Segment	Paris and Offenbach March	Mr D. E. Miller (MetO 19)
ESRO Meteorological Programme Board—1st Meeting	Paris March	Dr B. J. Mason, Director-General Dr K. H. Stewart (MetO 19)
ESRO GFGMS Sub-Group on Meteorological Data Processing Methods	Darmstadt March	Mr D. E. Miller (MetO 19)
Informal U.K./German/Dutch/Belgian Working Group on Joint North Sea Information Systems	Brussels March	Mr M. J. Blackwell, Assistant Director (Operational Instrumentation)
Meeting of the Inter-Union Commission on Solar–Terrestrial Physics	London March	Mr J. S. Sawyer, Director of Research
ESRO *ad hoc* Group on Space Meteorology, Sub-Group on the METEOSAT Ground Segment	Zürich April	Mr D. E. Miller (MetO 19)
Informal Meeting of Heads of Meteorological Services	Zürich April	Mr P. J. Meade, Director of Services
Spring Technical Meeting of the SHARE European Association (SEAS)	Nijmegen, The Netherlands April	Mr N. Bradbury, Assistant Director (Data Processing)
International Conference on Digital Communications	Loughborough April	Mr C. E. Goodison (MetO 5)
AFCENT Meteorological Committee—20th Meeting	Brunssum, The Netherlands May	Mr W. G. Harper (MetO 6)
Quadripartite Working Group on Meteorology (Army)	Fort Bliss, El Paso, Texas May	Dr P. G. F. Caton (MetO 6)
NATO Military Agency for Standardization Nuclear Biological Chemical Operational Procedures Inter-Service Working Party	Brussels May	Mr K. Bryant (MetO 6)
Co-ordinating Group of the Tactical Weather Network—17th Meeting	Rheindahlen May	Mr W. G. Harper (MetO 6) Mr F. J. Burton (MetO 6) Mr A. J. Norton (MetO 6)
Symposium on Planetary Atmospheres and Interiors, COSPAR	Madrid May	Dr R. Hide (Head of MetO 21) Mr B. R. May (MetO 19)
ESRO *ad hoc* Group on Space Meteorology	De Bilt May	Dr K. H. Stewart (MetO 19)
NATO Advisory Group on Meteorology	Brussels May	Mr J. S. Sawyer, Director of Research (Chairman)
15th Plenary Meeting of COSPAR	Madrid May	Mr E. Knighting, Deputy Director (Dynamical Research)

Subject	*Place and date*	*Attended by*
NATO Military Committee Meteorological Group—29th Meeting	Brussels June	Mr P. J. Meade, Director of Services Mr E. Evans (MetO 6) Mr D. W. Tann (MetO 6)
Meteorological Panel (Panel XII) of NATO Group AC/225	Brussels June	Dr P. G. F. Caton (MetO 6)
Anglo-French Meeting to discuss Concorde Meteorological Instrumentation	Bracknell June	Mr M. H. Freeman, Assistant Director (Special Investigations, (Chairman) Mr S. G. Cornford (MetO 9) Mr R. H. Hardy (MetO 9)
United Nations Conference on the Human Environment	Stockholm June	Dr B. J. Mason, Director-General
ESRO Meteorological Programme Board—2nd Meeting	Paris June	Dr B. J. Mason, Director-General
IUCRM Colloquium on Waves and Turbulence and their Effects on EM Propagation	San Diego, California June	Dr C. J. Readings (MetO 14)
IPLAN 1 (IGOSS)	Paris June	Mr R. F. Zobel, Assistant-Director (Central Forecasting)
Magneto-hydrodynamic Phenomena in Rotating Fluids (NATO Advanced Study Institute)	Cambridge June–July	Dr D. Acheson (MetO 21)
13th Congress OSTIV	Vrsac, Yugoslavia July	Mr T. A. M. Bradbury (MetO 2)
Planetary Atmospheres (NATO Advanced Study Institute)	Istanbul August–September	Dr R. Hide (Head of MetO 21) Dr G. E. Hunt (MetO 20)
Conference on Atmospheric Radiation, American Meteorological Society	Fort Collins, Colorado August	Dr G. E. Hunt (MetO 20)
NATO Advanced Study Group on Physics and Chemistry of the Upper Atmosphere	Orléans August	Mr C. J. De Jonckheere (MetO 19)
Commonwealth Air Transport Council —8th Meeting	London August–September	Mr L. Sugden Assistant Director (Public Services)
ESRO *ad hoc* Space Meteorology Group —11th Meeting	Dublin September	Dr B. J. Mason, Director-General Dr. K. H. Stewart (MetO 19)
Meeting of Directors of European Meteorological Services	Dublin September	Dr B. J. Mason, Director-General
2nd International Congress on History of Oceanography	Edinburgh September	Mr P. J. Meade, Director of Services Mr R. F. Zobel, Assistant Director (Central Forecasting)
ESRO GFGMS Sub-Group on Meteorological Data Processing Methods	Washington September	Mr D. E. Miller (MetO 19)
Planning meeting for WAMFLEX, a Multi-Aircraft Lee Wave Project in co-operation with NCAR	Boulder, Colorado September	Mr D. N. Axford (MRF) Mr J. M. Nicholls (MRF)
International Society of Biometeorology —6th Congress	Leiden, The Netherlands September	Mr L. P. Smith (MetO 8) Dr R. W. Gloyne (MetO 8) Mr S. F. Crawford (MetO 1)
Meeting on Meteorological Effects of Stratospheric Aircraft	Paris September	Dr R. J. Murgatroyd (MetO 20)
SHAPE Meteorological Committee Working Group for ACEWEX—10th Meeting	Kolsaas, Norway September	Mr W. G. Harper (MetO 6) Mr G. A. Cowling (MetO 6)
MOTNE Regional Planning Group—8th Meeting	Paris September	Mr C. H. Hinkel (MetO 7)

Subject	*Place and date*	*Attended by*
NATO CCMS Panel on Air Pollution Modelling	Paris October	Dr F. Pasquill (Head of Met O 14)
CENTO Regional Meteorological Advisory Group Meeting	Ankara October	Mr D. W. Tann (Met O 6) Mr G. Thornton-Smith (Met O 6)
NATO Sub-Group Meetings of MCMG Working Group on Weather Plans	London October	Mr D. W. Tann (Met O 6)
NATO MCMG 36th Meeting of Working Groups on Weather Plans and Weather Communications	London October	Mr D. W. Tann (Met O 6) Mr C. E. Goodison (Met O 5)
Symposium on Long-range Forecasting	Bad Homburg October	Mr M. K. Miles (Met O 13)
15th Conference on Radar Meteorology	Urbana, Illinois October	Dr J. R. Starr (Met O 15) Mr J. English (Met O 8)
ESRO Meteorological Programme Board	Paris October	Dr K. H. Stewart (Met O 19)
International Conference on the Convention on the Dumping of Wastes at Sea	London October	Mr H. C. Shellard (Met O 3) (WMO Observer)
2ATAF/NORTHAG Meteorological Sub-Committee—12th Meeting	Rheindahlen November	Mr W. G. Harper (Met O 6) Mr G. A. Cowling (Met O 6) Mr D. Hyde (Met O 6)
University of North Carolina and U.S. Environmental Protection Agency Symposium on Statistical Aspects of Air Quality Data	Raleigh, North Carolina November	Dr F. B. Smith (Met O 14)
NATO International Exercise De-Briefing Meeting	Bonn December	Mr K. Bryant (Met O 6) Mr L. S. Birch (Met O 6)
The Tripartite Technical Co-operation Programme Panel N-6	London December	Mr D. W. Tann (Met O 6) Mr K. Bryant (Met O 6) Mr L. S. Birch (Met O 6)

The following members of the staff were released during the year to take up international appointments overseas:

Mr G. E. H. Hills	Scientific Officer	Seconded in January to the Government of Zambia
Mr D. J. Skelly	Senior Scientific Officer	Seconded in January to the South Pacific Air Transport Council, Fiji
Mr A. S. Russell	Senior Scientific Officer	Seconded in February to the South Pacific Air Transport Council, Fiji
Mr P. F. Emery	Senior Scientific Officer	Seconded in August to the South Pacific Air Transport Council, Fiji (2nd tour)
Mr S. I. Nute	Senior Scientific Officer	Seconded in June to the Government of Antigua

The following staff returned to the Office from appointments overseas:

Mr D. G. Ward	Higher Scientific Officer	from Antigua
Mr W. McKay	Senior Scientific Officer	from Fiji
Mr D. McFarlane	Senior Scientific Officer	from Fiji
Mr. G H. Nicholl	Higher Scientific Officer	from Singapore
Mr M. H. Lloyd	Higher Scientific Officer	from Singapore

List of abbreviations used in this Section

WMO	—	World Meteorological Organization
ICAO	—	International Civil Aviation Organization
Unesco	—	United Nations Educational, Scientific and Cultural Organization
NAOS	—	North Atlantic Ocean Station
GARP	—	Global Atmospheric Research Programme
IOC	—	Intergovernmental Oceanographic Commission
IGOSS	—	Integrated Global Ocean Station System
RA VI	—	Regional Association VI
CMM	—	Commission for Marine Meteorology
IUGG	—	International Union of Geodesy and Geophysics
CBS	—	Commission for Basic Systems
FAO	—	Food and Agriculture Organization
IASH	—	International Association of Scientific Hydrology
CAS	—	Commission for Atmospheric Sciences
CIMO	—	Commission for Instruments and Methods of Observation
METEOSAT	—	European Geostationary Meteorological Satellite
EMTN	—	European Meteorological Telecommunications Network
ESRO	—	European Space Research Organization
GFGMS	—	Ground Facilities for a Geostationary Meteorological Satellite
NATO	—	North Atlantic Treaty Organization
IMCO	—	Inter-Governmental Maritime Consultative Organization
SHARE	—	Association to SHARE information of large IBM Computers
AFCENT	—	Allied Forces Central Europe
COSPAR	—	Committee on Space Research of the International Council of Scientific Unions
IUCRM	—	Inter-Union Commission for Radio Meteorology
IPLAN 1	—	Joint IOC/WMO Planning Group for IGOSS
OSTIV	—	Organisation Scientifique et Technique Internationale du Vol à Voile
NCAR	—	National Council for Atmospheric Research
SHAPE	—	Supreme Headquarters Allied Powers Europe
ACEWEX	—	Allied Command Europe Weather Exchange
MOTNE	—	Meteorological Operational Teleprinter Network Europe
CCMS	—	Committee on Challenges of Modern Society
CENTO	—	Central Treaty Organization
2ATAF/NORTHAG		Second Tactical Air Force/Northern Army Group

STAFF

GENERAL

The names of the principal officers of the Meteorological Office are listed on pages x–xi and the organization of the Office is shown in the diagram on page xii. At the end of 1972 the total number of posts of all grades was 3691, a decrease of 19 over the year. The actual strength at the end of the year was made up as follows:

Deputy Secretary	1
Under Secretary	1
Science Group	
Chief Scientific Officer (B)	1
Deputy Chief Scientific Officers	8
Senior Principal Scientific Officers	27
Principal Scientific Officers	105
Senior Scientific Officers	272
Higher Scientific Officers	483
Scientific Officers	522
Assistant Scientific Officers	1004
Administration Group	
Assistant Secretary	1
Principal	1
Executive Grades	24
Clerical Grades	161
Marine Staff	
Marine Superintendent	1
Nautical Officer Grades	10
Ocean Weather Ships and Base	
Officers and non-industrial grades	96
Crew	110
Technical and Signals Grades	343
Typing and miscellaneous non-industrial grades	149
Industrial employees	92
Locally entered staff and employees overseas	141

For the greater part of the year, the Office has been at its full allowable strength, and, at all levels, wastage has been covered by recruits of very good quality. No difficulty has been experienced in graduate recruitment and a substantial part of the intake has been very highly qualified. It is also notable that the grade of Assistant Scientific Officer has attracted a marked increase in school leavers offering passes in the General Certificate of Education at Advanced Level. There were no vacancies in the Technician Class during the year.

In 1972 the Office was able to accept 10 college-based Sandwich Course students for their extra-college periods of training. Reports on these students indicate that very useful work was obtained from most of them. In addition, 10 university undergraduates were offered employment during the long vacation. Five of these expressed real interest in joining the Office after graduation. Seven 'vacation consultants' from universities contributed to the work of the Office during the year.

HONOURS AND DISTINCTIONS

In the 1972 New Year Honours List Mr J. Harding was awarded the O.B.E.

The Director-General was awarded the Rumford Medal by the Royal Society.

The Buchan Prize was awarded jointly to Dr K. A. Browning and to Dr T. W. Harrold by the Royal Meteorological Society.

The L. G. Groves Memorial Prize for Meteorology was awarded to Mr P. R. Rowntree. The L. G. Groves Meteorological Observer's Award went to Mr J. Findlater. The L. G. Groves Second Memorial Award went to Mr J. I. P. Jones.

Miss S. A. Matthews was a joint winner of the Ferranti Prize awarded by the British Computer Society for the Part I examination.

APPENDIX I

BOOKS OR PAPERS BY MEMBERS OF THE STAFF

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APPENDIX II

A SELECTION OF THE LECTURES AND BROADCASTS GIVEN BY MEMBERS OF THE STAFF

ADAMS, R. J., M.Sc.

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BENWELL, G. R. R., M.A.

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BIRCH, L. S.

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BLACKWELL, M. J., M.A.

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BRADBURY, N., B.Sc.

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BROWNING, K. A., Ph.D., D.I.C.

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BROWNSCOMBE, J. L., Ph.D.

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BRYANT, K.
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CARSON, D. J., Ph.D.
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COLLIER, C. G., B.Sc.
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CORBY, G. A., B.Sc.
General circulation research in the British Meteorological Office. *National Science Centre, Melbourne, Australia.* 9 November.

CRABTREE, J., B.A.
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CRADDOCK, J. M., M.A.
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The work of the London Weather Centre.
London University Geographical Society. 31 January.
Technical Society of RAE Bedford. 19 October.
Weather services to the public. *Welsh Centre of the Royal Meteorological Society, University of Wales Institute of Science and Technology, Cardiff.* 1 November.

FREEMAN, M. H., O.B.E., M.Sc.
Objective forecasting of visibility at aerodromes. *Royal Meteorological Society, London.* 9 February.
Microscale temperature variations in the upper troposphere and lower stratosphere. *Atmospheric Environment Committee of the Aeronautical Research Council, London.* 26 April.

GADD, A. J., Ph.D.

Mathematics and physics in numerical weather prediction. *Department of Maritime Studies, University of Wales Institute of Science and Technology, Cardiff.* 29 November.

Mathematical numerical models for weather forecasting. *Department of Mathematics, Exeter University.* 10 November.

GEORGE, D. J.

Forecasting for gliding.

National Gliding Championship, Shobdon, Herefordshire. 1–4 June.

Regional Gliding Championship, Lasham, Hants. 22 July.

Windchill and exposure and snow, ice, avalanches. *Mountain Weather Field Study Course, Betws-y-coed, Caernarvonshire.* 16–23 August.

GLOSTER, J.

Demonstration of a desk-top tornado. *Contribution to BBC 1 Television Education Section.* 14 and 19 July.

GOLDSMITH, P., M.A.

Microphysics of hydrometeor growth, *Welsh Centre of the Royal Meteorological Society. University of Wales, Institute of Science and Technology, Cardiff.* 20 April.

GOODISON, C. E., C.Eng., M.I.E.R.E.

Digital facsimile techniques in meteorological telecommunications. *International Conference on digital processing of signals in communications, Loughborough University of Technology.* 11–13 April.

GRANT, J. R., B.Sc.

Course of four lectures on meteorology for student pilots. *Duddeston Manor Further Education Centre, Birmingham.* 30 October, 6, 13 and 20 November.

Talk on 'Weather' to *Countryside Appreciation Course, Warwickshire College of Agriculture, Moreton Morrell, Warwicks.* 18 and 25 May.

HARROLD, T. W., Ph.D., D.I.C.

Identification of preferred areas of shower development by means of high-power radar. *Royal Meteorological Society, London.* 19 January.

The structure and mechanism of widespread precipitation.

Imperial College, London. 24 February.

Reading University. 9 June.

Summer Meeting of the Royal Meteorological Society, London. 27 June.

The Dee Weather Radar Project. *WMO Symposium, Geilo, Norway.* 1 August.

Measurement by radar of precipitation falling over an area. *Institution of Electrical Engineers, Mersey and North Wales Centre, Electronics and Control Section, Fourth Annual Liverpool Colloquium.* 4 October.

Some results of radar measurements of precipitation in North Wales. *Scottish Centre, Royal Meteorological Society, Edinburgh.* 17 November.

HIDE, R., Sc.D., F.R.S.

Rotating fluids. *Theoretical Physics Division, Atomic Energy Research Establishment, Harwell, Berks.* 1 February.

Hydromagnetic oscillations of the Earth's core. *Royal Astronomical Society, London.* 11 February.

Motions in planetary atmosphere. *Geophysical Fluid Dynamics Laboratory, Princeton University, New Jersey, U.S.A.* 29 February.

Baroclinic waves.

Institute for Mathematics and its Applications, Southampton University. 16 May.

Royal Meteorological Society, London. 21 June.

Circulation of Venus's atmosphere. *Clarendon Laboratory, Oxford.* 21 November.

HULL, O. M.

Meteorology and sailing. *Course of* 12 *lectures to Inner London Education Authority Evening Classes aboard the Cutty Sark at Greenwich.* September–December.

HUNT, G. E., Ph.D., F.I.M.A.

Radiative properties of terrestrial water and ice clouds at near infrared thermal window wavelengths. *International Cloud Physics Conference, London.* 26 August.

Interpretation of spectroscopic observations of Venus. *North Atlantic Treaty Organization Advanced Study Institute, Istanbul.* 1 September.

Interpretation of spectroscopic observations of Jupiter. *North Atlantic Treaty Organization Advanced Study Institute, Istanbul.* 1 September.

Detection of cirrus clouds using the NIMBUS E SCR radiometer. *Department of Atmospheric Physics, Oxford University.* 5 October.

Structure and composition of atmosphere and clouds of Venus. *Department of Atmospheric Physics, Oxford University.* 21 November.

HUNT, G. S. F.

Four lectures on meteorological aspects of the Yachtmaster's Certificate. *Midland Sailing Club, Edgbaston, Birmingham.* February–April.

HOOPER, A. H.

A new operational radiosonde system. *Joint Royal Meteorological Society/Institution of Electrical Engineers Symposium at the Institution of Electrical Engineers, Savoy Place, London.* 24 April.

JOHNSON, G. C.

Meteorology and mountain climbing. *Course of three lectures to Youth and Community Service Adventure Training students, College Youth Centre, Brent, Middx.* February–March.

JONAS, P. R., Ph.D., D.I.C.

Cloud droplet growth by coalescence. *Royal Meteorological Society Summer Meeting, Manchester.* 28 July.

The coalescence of droplets in a turbulent cloud. *International Cloud Physics Conference, London.* 22 August.

The growth of precipitation at a cold front. *International Cloud Physics Conference, London.* 25 August.

KIRK, T. H., B.Sc.

Discussion with Italian meteorologists on weather prospects for Italy during September. *BBC Italian Service.* 1 September.

KNIGHTING, E., B.Sc.

Modern weather forecasting. *John Ray Society, St Catherine's College, Cambridge.* 16 October.

LAWRENCE, E. N., B.Sc.

Air pollution in urban areas. *The Geography Club, Reading University.* 9 November.

MCKELLAR, H. A.

Some aspects of mountain weather. *Scottish Centre of the Royal Meteorological Society, Edinburgh.* 20 October.

MASON, B. J., C.B., D.Sc., F.R.S.

The role of satellites in observing and forecasting the global behaviour of the atmosphere. *Mathematical and Physical Society, Royal College of Science, London.* 13 January.

The use of mathematics in weather forecasting. *Mathematics Club, Imperial College, London.* 10 February.

Meteorology and the future to AD 2000. *Welsh Centre of the Royal Meteorological Society, University of Wales Institute of Science and Technology, Cardiff.* 16 March.

Numerical weather prediction.
Department of Natural Philosophy, Glasgow University. 19 April.
CERN, Geneva. 18 May.

Global Atmospheric Research Programme.
CERN, Geneva. 19 May.
AERE, Harwell, Berks. 16 June.

World Weather Watch. *ASLIB (Association of Special Libraries and Information Bureaux), Royal Aeronautical Society, London.* 14 June.

The use of mathematical models in the forecasting of weather and climate. *Civil Service College, Sunningdale, Berks.* 20 September.

The physics of the thunderstorm.
Physics Society, Christ's College, Cambridge. 12 October.
Maxwell Society, King's College, London. 23 October.
H. G. Wells Society of Imperial College, London. 4 December.

The physics and physical chemistry of the thunderstorm. *Chemical and Physical Societies, University of Surrey, Guildford.* 12 December.

MASON, P. J., Ph.D.

A laboratory study of sloping convection in a container with sloping end walls. *Reading University.* 21 January.

Baroclinic waves and instabilities. *Royal Meteorological Society, London.* 21 June.

MASON, S. C.

Weather and sailing. *Royal Victoria Sailing Club, Fishbourne, I.O.W.* 7 January.

MEADE, P. J., O.B.E., B.Sc.
The history of WMO with special reference to oceanography. *Second International Congress on the History of Oceanography (Challenger Expedition Centenary), Edinburgh.* 14 September.

MILLER, D. E., B.A.
The role of satellites in meteorology. *British Association for the Advancement of Science, Leicester.* 8 September.

OGDEN, R. J., B.Sc.
Forecasting for oil rigs. *Royal Meteorological Society, London.* 16 February.
Contribution to BBC 1 TV programme concerning oil and gas drilling operations in the North Sea. 21 February.
Contribution to Thames Television programme concerning weather forecasting and its application to medicine. 28 June.
Weather forecasting. *British Association of Young Scientists, University of Kent, Canterbury.* 10 July.
Recorded contribution to Norddeutscher Rundfunk educational TV programme on the effects of the Clean Air Act (sponsored by Central Office of Information). 13 September.

PARKER, G. H., B.Sc.
The work of London Weather Centre. *Chelsea Polytechnic.* 29 February.
Meteorology Course of 6 lectures to Adult Evening Institute, Chiswick. January–March.
Meteorology Course of 11 lectures to Institute for Further Education, Ewell, Surrey. September–December.

PARREY, G. E., B.Sc.
Forecasting for gas and electricity industries. *Royal Meteorological Society, London.* 16 February.

PASQUILL, F., D.Sc.
Some aspects of boundary layer description. *Presidential address to the Royal Meteorological Society, London.* 19 April.

RATCLIFFE, R. A. S., M.A.
Recent work relating sea temperature anomalies and long-range forecasting. *Royal Meteorological Society, London.* 18 October.
Long-range forecasting.
Shoreditch College, Englefield Green, Surrey. 13 November.
Welsh Centre of the Royal Meteorological Society, University of Wales Institute of Science and Technology, Cardiff. 22 November.

READINGS, Ph.D., D.I.C.
Atmospheric probing using a tethered balloon. *Joint meeting of the Royal Meteorological Society and Institution of Electronic and Radio Engineers, London.* 24 April.

RIGDEN, H. L.
Meteorology. *Course of six lectures to Workers Educational Association, Southampton.* January–February.

SALTER, PAULINE M., B.Sc.
Areal rainfall analysis by computer.
Conference of River Authority engineers, Cranfield, Beds. 19 July.
WMO Symposium, Geilo, Norway. 4 August.

SAWYER, J. S., M.A., F.R.S.
Man-made carbon dioxide and the 'greenhouse' effect on climate. *Joint conference of 'Nature' and the Royal Institution, London.* 28 April.
Numerical weather prediction. *World Weather Watch 10th Anniversary ceremony, Geneva.* 26 May.
Possible effects of human activity on world climate. *Manchester Branch of the Royal Meteorological Society.* 24 October.
Climate changes and the possibility of effects of man's activities. *National Physical Laboratory, Teddington.* 3 November.

SIMMONS, E. L., M.A., Ph.D.
Ozone as a stratospheric Lagrangian tracer. *International Association of Meteorology and Atmospheric Physics, Ozone Commission Symposium, Arosa, Switzerland.* 22 August.

SMITH, F. B., Ph.D.

The prediction of high concentrations of sulphur dioxide in London and Manchester air.

Bristol University. 5 July.

Department of Applied Mathematics, Exeter University. 27 October.

Pollution and weather. *Royal Meteorological Society Popular and Sixth Form Lecture, London*. 7 and 8 December.

SPALDING, T. R.

Satellite data for tropical forecasting. *Symposium on Remote Sensing of Man's Environment, Bristol University*. 2 October.

STARR, J. R., Ph.D., D.I.C.

Clouds, rain and rainmaking.

Education Group at Keele University. 31 January.

National Federation of Business and Professional Women's Clubs of Great Britain and Northern Ireland, Worcester. 26 September.

Physical Society, Leicester University. 9 November.

Clouds, rain and the Meteorological Office. *St John's Worcester Women's Fellowship*. 6 June.

Thunderstorms, tornadoes and hurricanes. *Twenties Club, Worcester*. 7 June.

Why does it rain? *Scout Leaders, Blackwell Court, Bromsgrove, Worcs*. 17 June.

Boundary layer studies with the Defford high-power radar. *Geophysical Sciences Seminar, Chicago University*. 9 October.

Doppler radar measurements of clear-air-turbulence. *15th Radar Meteorology Conference, Urbana, Illinois*. 12 October.

Clear-air studies with the Defford high-power radar facility. *Johns Hopkins University, Silver Spring, Maryland*. 19 October.

WOODS, J. D., Ph.D.

Observations of vertical motions on fronts in the thermocline. *Department of Applied Mathematics and Theoretical Physics, Cambridge University*. 29 March.

Structure of fronts off Malta. *SACLANT, Anti-submarine Warfare Research Centre, La Spezia, Italy*. 12 April.

ZOBEL, R. F., O.B.E., B.Sc.

Contribution to *Southern ITV programme 'My Scene the South'*. 16 October.

Weather Routeing of ships on the North Atlantic. *Second International Congress on the History of Oceanography (Challenger Expedition Centenary), Edinburgh*. 14 September.

APPENDIX III

PUBLICATIONS

The publications prepared by the Meteorological Office are generally issued by Her Majesty's Stationery Office as official publications. Catalogues listing all the publications which may be purchased through the sales offices or usual agents of Her Majesty's Stationery Office, or direct from the Meteorological Office at Bracknell, are sent free to any applicant.

The following publications were issued during the period of this Report:

PERIODICAL

Annual Report on the Meteorological Office 1971.

Daily Aerological Record containing information in respect of meteorological conditions in the upper air for the British Isles (to 20 December 1972).

Daily Weather Report containing weather maps for the northern hemisphere, British Isles, etc., and data (to 31 December 1972).

Daily Weather Report, Overseas Supplement containing surface and upper air data (to 10 February 1971).

Monthly Summary of the *Daily Weather Report* (to November 1972).

Monthly Weather Survey and Prospects, a monthly publication containing climatological data for the United Kingdom, the weather of the past month, a general survey and inference, and weather prospects for the coming month in the United Kingdom; a supplementary document, containing survey, inference and prospects only, is published in mid-month (to 15 December 1972).

Estimated Soil Moisture Deficit and Potential Evapotranspiration over Great Britain, a seasonal fortnightly publication providing estimates of soil moisture deficit in map form and as a tabular statement for river authority areas (to 14 December 1972).

Sea Ice Charts (daily) (to 31 December 1972).

Monthly (coloured) Ice Maps (to September 1971).

Meteorological Magazine (monthly) (to December 1972).

Monthly Weather Report (to June 1972).

Marine Observer (quarterly) (to October 1972).

British Rainfall—Annual Volumes for 1963, 1964 and 1965.

British Rainfall Supplement—1961–1965.

SERIAL

Geophysical Memoirs:

Volume XVI

116. British Isles weather types and a register of the daily sequence of circulation patterns 1861–1971, by H. H. Lamb, M.A.
117. Northern hemisphere monthly mean 500-millibar and 1000–500-millibar thickness charts and some derived statistics (1951–66), by B. J. Moffitt and R. A. S. Ratcliffe, M.A.

Scientific Papers:

33. Hydromagnetic waves on a beta-plane: A numerical study of the dispersion relationship, by R. Hide, Sc.D., F.R.S. and M. V. Jones, B.Sc.

OCCASIONAL

Meteorological Glossary, 5th Edition (1972), edited by D. H. McIntosh, M.A., D.Sc.

Printed in Scotland for Her Majesty's Stationery Office by D. J. Clark Limited, Glasgow
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